TM 1–424

WAR DEPARTMENT

TECHNICAL MANUAL

AIRCRAFT HARDWARE AND MATERIALS

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TECHNICAL MANUAL No. 1-424

WAR DEPARTMENT,
WASHINGTON, June 11, 1942.

AIRCRAFT HARDWARE AND MATERIALS

SECTION I

GENERAL

1. Purpose.—*a.* The purpose of this manual is to provide aircraft maintenance personnel with general information about the principal materials and hardware used in aircraft construction and repair. The subject matter is not to be construed as supplementing or replacing information contained in specifications or the Air Corps Standards Book. Requirements for various aircraft materials and specific items of hardware must conform to existing specifications when used in the maintenance and repair of aircraft.

b. Materials used in aircraft construction are carefully selected for specific properties. Constant research and experimentation have resulted in the successful production and application of lightweight metals which have strength and other qualities necessary to withstand the rigorous treatment to which modern military aircraft are subjected. Likewise, new and improved nonmetallic materials have been produced for use in aircraft. Despite the high degree of development of both material and design, failures occur under certain conditions. Therefore, a knowledge of the correct application and treatment of materials is of value in the inspection and maintenance of aircraft to insure efficient and safe operation.

2. Definitions.—An understanding of the following terms is necessary in the study of materials and their use in aircraft construction:

a. Terms relating to physical characteristics.—(1) *Hardness.*—Hardness refers to the ability of a material to resist abrasion, penetra-

tion, indentation, or cutting action. The wearing qualities of a material are dependent upon its hardness. Hardness and strength are properties which are closely related. Parts such as bearings and stressed shafts must possess hardness to resist wear and strength to sustain loads. Methods of testing materials for hardness are explained in TM 1-423.

(2) *Brittleness.*—Brittleness is the property of a material which permits little bending or deformation without fracture. Brittleness and hardness are closely associated.

(3) *Malleability.*—A metal which can be hammered, rolled, or pressed into various shapes without fracturing or other detrimental effects is said to be malleable. This condition is necessary in sheet metal which is worked into curved shapes such as cowling, fairing, wing tips, etc. Malleability and brittleness are opposite characteristics.

(4) *Ductility.*—Ductility is the property of a material which permits it to be permanently drawn, bent, or twisted into various shapes without fracture. Wire used in control cables and electrical conductors is drawn from ductile material. Ductility is similar to malleability.

(5) *Elasticity.*—Elasticity is that property which enables a material to return to its original shape when the force which causes the change of shape is removed. This property is especially desirable in springs.

(6) *Toughness.*—A material which possesses toughness will withstand tearing or shearing, and may be stretched or otherwise deformed without fracturing. Toughness is a desirable property in aircraft materials, and is the opposite of brittleness.

(7) *Heat conductivity.*—Heat conductivity is the property of a material which determines the rate of transfer of heat within the material. Metals vary in their ability to conduct heat. Aluminum alloy has a relatively high rate of heat conductivity, and therefore is used in cylinder heads of air-cooled engines to dissipate the heat of combustion.

(8) *Tensile strength.*—The tensile strength of a material is its resistance to a force which tends to pull it apart. Tensile strength is measured in pounds per square inch and is calculated by dividing the load (in pounds) required to pull the material apart by its cross-sectional area (in square inches).

(9) *Compressive strength.*—The compressive strength of a material is its resistance to a crushing force. Compressive strength of a material is measured in pounds per square inch. Landing gear shock absorbers are subjected to compressive forces.

(10) *Shearing strength.*—The resistance offered by a material to a force tending to cause one layer of the material to slide over an adjacent layer is known as its shearing strength. Two riveted plates in tension subject the rivets to a shearing force. Usually the shearing strength of a material is either equal to or less than its tensile or compressive strength.

(11) *Bending strength.*—Bending may be described as the deflection or curving of a member due to forces acting upon it. The bending strength of material is the resistance it offers to deflecting forces.

(12) *Torsional strength.*—Torsion is a twisting force such as would occur in a member fixed at one end and twisted at the other. The torsional strength of material is its resistance to torsion.

(13) *Fatigue resistance.*—(*a*) Fatigue occurs in materials which are subjected to frequent reversals of loading or repeatedly applied loads, if the fatigue limit is reached or exceeded. Repeated vibration or bending will ultimately cause a minute crack to occur at the weakest point of a material. As vibration or bending continues the crack progresses until complete failure of the part results. This is known as fatigue failure and resistance to this condition is known as fatigue resistance.

(*b*) Fatigue failures in aircraft parts may originate from a number of causes dependent upon design or processing. Many instances of failure may be traced to nicks, scratches, corrosion, or other damage to the surface of metals. It is highly important that care be exercised to avoid tool marks or other damage to metals to prevent fatigue failures.

(*c*) Cracks in magnetic material which are not revealed by visual inspection may be detected by the magnaflux inspection method. In this process the material to be inspected is magnetized and covered with iron filings or black oxide of iron suspended in a light petroleum oil. Any crack or break in the surface is made readily visible by the accumulation of filings about it. This method of inspection is explained in TM 1–423.

(14) *Strength-weight ratio.*—The relationship between the strength of a material and its weight per cubic inch expressed as a ratio is known as the strength-weight ratio. This ratio forms the basis of comparing the desirability of various materials for use in aircraft construction. Neither strength nor weight alone can be used as a means of true comparison.

(15) *Work-hardening.*—The hardening of metals by cold working or forming is termed work-hardening. Stainless steel is hardened by cold working and heat treating. Bending or hammering copper tubing produces undesirable work-hardening characteristics. Vibra-

tion also produces undesirable work-hardening effects. These effects may be removed by annealing to lessen the possibility of fracturing.

b. Terms relating to heat treatment.—Heat treatment is a process which involves the heating and cooling of a metal (in its solid state) to obtain certain desirable properties. By heat treatment, a hard metal may be made soft, a ductile metal made elastic, or a soft metal made tough and strong. Heat treatment includes the processes of hardening, annealing, tempering, normalizing, and case-hardening. (Details of these processes are given in TM 1–423.)

(1) *Hardening.*—The process of hardening consists of heating a metal slightly above a predetermined temperature called the critical point of the metal, and rapidly cooling by quenching in one of various media depending on the properties desired and the chemical composition of the metal.

(2) *Annealing.*—Annealing is done to induce softness, reduce stresses, alter ductility, or refine the grain structure of metal. It is accomplished by heating a metal above its critical temperature and allowing it to cool slowly.

(3) *Tempering.*—Tempering may be considered a form of annealing done to remove internal strains in metal which develop during the hardening process. It is accomplished by heating the metal to a point below its critical temperature, and cooling in one of various media.

(4) *Normalizing.*—Normalizing relieves internal strains in steel which develop during machining, welding, or forging processes. It consists of heating a metal to a point above its critical temperature and cooling in still air.

(5) *Case-hardening.*—Case-hardening is a combined process of carburizing (heating an iron-base alloy to an elevated temperature in contact with carbonaceous material) and heat treatment, to produce a hard, wear-resisting surface and a soft tough core. Such parts as gears, piston pins, roller bearings, etc., are case-hardened.

SECTION II

FERROUS METALS

3. General.—*a.* The term "ferrous" applies to the group of metals having iron as the principal constituent.

b. Iron obtained directly from the smelting process contains an excess of carbon and various impurities which render it undesirable for commercial use. After refining, only small amounts of carbon and impurities remain in the iron. This process greatly improves the physical properties of the metal, making it adaptable for industrial use.

c. The presence of limited quantities of carbon greatly affects the useful properties of iron. If carbon in percentages ranging up to approximately 1.00 percent is added to iron, the product will be vastly superior to iron in toughness, strength, hardness, etc., and is classified as carbon steel. Numerous types of carbon steels, ranging from mild to very hard, can be produced by heat treating the various metals having carbon contents within this range. Manganese, silicon, sulfur, and phosphorus are also present in steel in small percentages.

d. Carbon steel forms the base of the alloy steels which are produced by combining carbon steel with sufficient quantities of certain other elements known to improve the properties of steel. Silicon, manganese, nickel, vanadium, tungsten, molybdenum, and chromium are the common elements used and are known as alloying elements. Each element imparts special properties to the alloy in which it is used. These elements alter the rate and temperature at which internal structural changes take place during the heat treatment, resulting in a finer quality of alloy. Except in rare instances, the superiority of steel alloys over carbon steels is demonstrated only after proper heat treatment. The composition of the principal steels used in aircraft construction is given in table I.

4. Forms and shapes of steel.—Steel stock is manufactured in forms of sheets, bars, rods, tubing, extrusions, formings, forgings, and castings.

a. Sheet metal is made in a number of sizes and thicknesses. Specifications designate thicknesses in thousandths of an inch. A comparison of sheet metal and wire gages is given in table II.

b. Bars and rods are supplied in a variety of cross-sectional shapes, such as round, square, rectangular, hexagonal, and octagonal.

c. Tubing can be obtained in round, oval, rectangular, and streamlined cross-sectional shapes. The size of tubing is generally specified by outside diameter and wall thickness.

d. Extrusions are produced by forcing metal, under pressure, through dies having the desired cross-sectional shape.

e. Formings are manufactured from sheet metal. The sheet metal is usually formed cold in such machines as presses, bending brakes, draw benches, and rolls. Small angles, U-channels, and large curved sections are produced in this manner.

TABLE I.—*Composition of steels used in aircraft construction* [1]

SAE No.	Composition (approximate percentage)									
	Carbon	Silicon	Manganese	Phosphorus (maximum)	Sulfur (maximum)	Chromium	Nickel	Molybdenum	Vanadium	Other (maximum)
1025	0.20 to 0.30		0.50 to 0.80	0.045	0.050					
1035	.30 to .40	0.15 to 0.35	.50 to .80	.045	.050					
1045	.40 to .50	.15 to .35	.50 to .80	.045	.050					
1095	.90 to 1.05	.15 to .35	.25 to .60	.040	.050					
2330	.25 to .35	.15 to .30	.50 to .80	.040	.050		3.25 to 3.75			
X-4130	.25 to .35	15 to .30	.50 to .80	.040	.050	0.80 to 1.10		0.15 to 0.25		
X-4135	.32 to .39		.40 to .60	.040	.045	.80 to 1.10		.15 to .25		
4140	.35 to .45	.15 to .30	.60 to .90	.040	.050	.80 to 1.10		.15 to .25		
3140	.35 to .45	.15 to .30	.60 to .90	.040	.050	.45 to .75	1.00 to 1.50			
3250	.45 to .55	.15 to .30	.30 to .60	.040	.050	.90 to 1.25	1.50 to 2.00			
X-4340	.35 to .42		.60 to .90	.025	.025	.60 to .90	1.65 to 2.00	.20 to .30		
4615	.10 to .20		.40 to .70	.040	.050		1.65 to 2.00	.20 to .30		
6135	.30 to .40	.15 to .30	.50 to .80	.040	.045	.80 to 1.10			0.15 to 0.20	
6150	.45 to .55	.15 to .30	.60 to .90	.040	.045	.80 to 1.10			.15 to .20	
6195	.90 to 1.05	.15 to .30	.20 to .45	.030	.035	.80 to 1.10			.15 to .20	
51235	.30 to .40	.50 (max.)	.50 (max.)	.035	.035	11.5 to 14.0				Al. 0.95 to 1.35

[1] Compiled from War Department specification.

f. Forgings are shaped or formed by pressing or hammering heated metal in dies. The forging process compresses the metal and increases the hardness.

g. Castings are produced by pouring molten metal into molds. The casting is finished by machining.

5. Methods of identifying steel stock.—*a*. A numerical index system devised by the Society of Automotive Engineers (SAE) identifies the composition of SAE steels. Each SAE number consists of a group of digits, the first of which represents the type of steel; the second, the percentage of the principal alloying element; and usually the last two or three digits, the percentage (in hundredths of one percent) of carbon in the alloy.

(1) The common SAE symbols used in the identification of steels are as follows:

Type of steel:	*Classification*
Carbon	1xxx
Nickel	2xxx
Nickel-chromium	3xxx
Molybdenum	4xxx
Chromium	5xxx
Chromium-vanadium	6xxx
Tungsten	7xxx
Silicon-manganese	9xxx

(2) Examples of the application of SAE numbers are as follows:

(*a*) The SAE number 4150 indicates a molybdenum steel containing 1 percent molybdenum and 0.50 percent carbon.

(*b*) The SAE number 1010 denotes a carbon steel containing 0.10 percent carbon. The first 0 indicates the lack of a principal alloying element, and hence a plain carbon steel.

(*c*) The percentages indicated in the SAE number are average; for example, the carbon content of SAE 1050 steel may vary from 0.45 to 0.55 percent and is indicated as 0.50 percent.

b. In order to provide a visual means of identification for steel tubes, bars, and sheets stocked by the Army Air Forces, such material is marked with an identifying color code. The identification marking consists of colored stripes as follows:

Three sets of stripes, one in the middle and one near each end, are painted around each bar and tube and across one face of each sheet. Each set of stripes consists of two parallel stripes, the one a broad stripe approximately 5 inches wide, and the other a narrow stripe approximately 2 inches wide. When the broad or narrow stripe consists of two colors, one-half the width of the stripe is used for each color. The 2-inch stripe represents the last two digits of the steel

number. The 5-inch stripe represents the preceding digits of the steel number. Table III lists the combinations of colors used to identify the various steels.

6. Aircraft steels and their uses.—*a. Carbon steels.*—(1) Steel containing carbon in percentages ranging from 0.10 to 0.30 percent is classed as low carbon steel. The equivalent SAE numbers range from 1010 to 1030. Steels of this grade are used for the manufacture of articles such as safety wire, certain nuts, cable bushings, and threaded rod ends. This steel in sheet form is used for secondary structural parts and clamps and in tubular form for moderately stressed structural parts.

(2) Steel containing carbon in percentages ranging from 0.30 to 0.50 percent is classed as medium carbon steel. This steel is especially adaptable for machining, forging, and where surface hardness is important. Certain rod ends, light forgings, and parts such as Woodruff keys are made from SAE 1035 steel.

(3) Steel containing carbon in percentages ranging from 0.50 to 1.05 percent is classed as high carbon steel. The addition of other elements in varying quantities adds to the hardness of this steel. In the fully heat-treated condition it is very hard and will withstand high shear and wear but little deformation. It has limited use in aircraft construction. SAE 1095 in sheet form is used for making flat springs and in wire form for making coil springs.

b. Nickel steels.—The various nickel steels are produced by combining nickel with carbon steel. Steels containing from 3 to 3.75 percent nickel are commonly used. Nickel increases the hardness, tensile strength, and elastic limit of steel without appreciably decreasing the ductility. It also intensifies the hardening effect of heat treatment. SAE 2330 steel is used extensively for aircraft parts such as bolts, terminals, keys, clevises, and pins.

c. Chromium steels.—Chromium steel is high in hardness, strength, and corrosion-resistant properties. SAE 51235 steel is particularly adaptable for heat-treated forgings which require greater toughness and strength than may be obtained in plain carbon steel. It may be used for such articles as the balls and rollers of antifriction bearings.

d. Chrome-nickel steels.—(1) Chromium and nickel in various proportions mixed with steel form the chrome-nickel steels. The general proportion is about two and one-half times as much nickel as chromium. For all ordinary steels in this group the chromium content ranges from 0.45 to 1.25 percent, while the nickel content ranges from 1 to 2 percent. Both nickel and chromium influence the properties of steel; nickel toughens it, while chromium hardens it. Chrome-nickel steel is used for machined and forged parts requiring strength, ductility, toughness,

and shock resistance. Parts such as crankshafts, connecting rods, etc., are made of SAE 3140 steel.

(2) Chrome-nickel steel containing approximately 18 percent chromium and 8 percent nickel is known as corrosion-resistant steel. In plate and sheet form it is used extensively in the fabrication of engine exhaust stacks, collector rings, and manifolds.

e. Chrome-vanadium steels.—The vanadium content of this steel is approximately 0.18 percent and the chromium content approximately 1.00 percent. Chrome-vanadium steels when heat-treated have excellent properties such as strength, toughness, and resistance to wear and fatigue. A special grade of this steel in sheet form can be cold-formed into intricate shapes. It can be folded and flattened without signs of breaking or failure. Chrome-vanadium steel with medium high carbon content (SAE 6150) is used to make springs. Chrome-vanadium steel with high carbon content (SAE 6195) is used for ball and roller bearings.

f. Chrome-molybdenum steels.—Molybdenum in small percentages is used in combination with chromium to form chrome-molybdenum steel; this steel has important applications in aircraft. Molybdenum is a strong alloying element, only 0.15 to 0.25 percent being used in the chrome-molybdenum steels; the chromium content varies from 0.80 to 1.10 percent. Molybdenum raises the ultimate strength of steel without affecting ductility or workability. Molybdenum steels are tough, wear resistant, and harden throughout from heat treatment. They are especially adaptable for welding and for this reason are used principally for welded structural parts and assemblies. Tubing made from X-4130 steel is used for structural parts such as welded fuselages, engine mounts, and landing gear structures.

TABLE II.—*Comparison of sheet metal and wire gages* [1]

Gage No.	Decimal equivalents of gage numbers				
	AWG [2]	NW [3]	MW [4]	US [5]	BW [6]
000000 (6-0)	0.5800	0.4615	0.004	0.4688	
00000 (5-0)	.5165	.4305	.005	.4375	0.500
0000 (4-0)	.4600	.3938	.006	.4063	.454
000 (3-0)	.4096	.3625	.007	.3750	.425
00 (2-0)	.3648	.3310	.008	.3438	.380
0 (1-0)	.3249	.3065	.009	.3125	.340

[1] Compiled from A. C. Technical Order 23-1-3.

[2] Brown & Sharp and American Standard Wire. Applied to: Nonferrous wire and sheet aluminum, aluminum alloy, copper and brass rod.

[3] National Wire, Roebling, Washburn & Moen, American Steel & Wire, and U. S. Steel Wire. Applied to: All bare, galvanized, and annealed steel wire, all tinned steel wire, and corrosion-resisting steel.

[4] Music Wire. Applied to: Spring wire (piano wire).

[5] United States Standard. Applied to: All commercial planished, galvanized, tinned, and terne plate of iron and steel, sheet steel.

[6] Birmingham Wire, Stubs Iron Wire. Applied to: All tubing, sheet spring steel.

TABLE II.—*Comparison of sheet metal and wire gages*—Continued

Gage No.	Decimal equivalents of gage numbers				
	AWG	NW	MW	US	BW
1	.2893	.2830	.010	.2813	.300
2	.2576	.2625	.011	.2656	.284
3	.2294	.2437	.012	.2500	.259
4	.2043	.2253	.013	.2344	.238
5	.1819	.2070	.014	.2188	.220
6	.1620	.1920	.016	.2031	.203
7	.1443	.1770	.018	.1875	.180
8	.1285	.1620	.020	.1719	.165
9	.1144	.1483	.022	.1563	.148
10	.1019	.1350	.024	.1406	.134
11	.0907	.1205	.026	.1250	.120
12	.0808	.1055	.029	.1094	.109
13	.0720	.0915	.031	.0938	.095
14	.0641	.0800	.033	.0781	.083
15	.0571	.0720	.035	.0703	.072
16	.0508	.0625	.037	.0625	.065
17	.0453	.0540	.039	.0563	.058
18	.0403	.0475	.041	.0500	.049
19	.0359	.0410	.043	.0438	.042
20	.0320	.0348	.045	.0375	.035
21	.0285	.0317	.047	.0344	.032
22	.0253	.0286	.049	.0313	.028
23	.0226	.0258	.051	.0281	.025
24	.0201	.0230	.055	.0250	.022
25	.0179	.0204	.059	.0219	.020
26	.0159	.0181	.063	.0188	.018
27	.0142	.0173	.067	.0172	.016
28	.0126	.0162	.071	.0156	.014
29	.0113	.0150	.075	.0141	.013
30	.0100	.0140	.080	.0125	.012
31	.0089	.0132	.085	.0109	.010
32	.0080	.0128	.090	.0102	.009
33	.0071	.0118	.095	.0094	.008
34	.0063	.0104	.100	.0086	.007
35	.0056	.0095	.106	.0078	.005
36	.0050	.0090	.112	.0070	.004
37	.0045	.0085	.118	.0066	
38	.0040	.0080	.124	.0063	
39	.0035	.0075	.130		
40	.0031	.0070	.138		

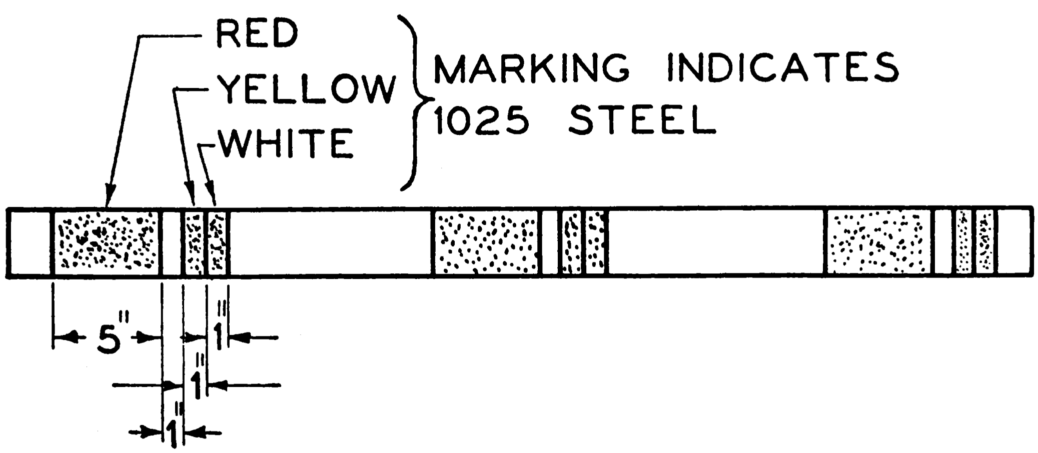


FIGURE 1.—Marking of steel.

TABLE III.—*Identification of steels*[1]

Broad stripe		Narrow stripe	
Color	First digits	Color	Last 2 digits
Red	10	Brown and yellow	521
Red and white	12	Purple	713
Red and yellow	13	Purple and yellow	716
Yellow	23	Red and black	00
Yellow and green	25	Red	10
Green	31	Red and green	12
Blue	32	Red and white	15
Brown	33	Yellow	20
Black	34	Yellow and white	25
Black and white	41	Black	30
Red and black	46	Black and white	35
Khaki	51	Green	40
Red and blue	53	Green and white	45
White	61	Black and green	46
Red and brown	72	Blue	50
Blue and yellow	76	Brown	60
Blue and brown	92	Brown and white	65
Brown and white	512	Khaki	95

[1] Compiled from Air Corps Bulletin No. 43.

SECTION III

NONFERROUS METALS

7. General.—The term "nonferrous" refers to all metals other than iron and those alloys which have elements other than iron as the principal constituent.

8. Aluminum and its alloys.—*a.* Aluminum is a white, lustrous metal, light in weight and corrosion resistant. The thermal conductivity of aluminum is very high. It is ductile, malleable, and nonmagnetic. Commercial aluminum, usually referred to as pure aluminum, ordinarily contains not more than 1 percent of other elements. These elements, chiefly iron and silicon, in such small percentages are regarded as impurities.

b. Aluminum combined with various percentages of other metals, generally copper, manganese, and magnesium, form the aluminum alloys which are used in aircraft construction. Aluminum alloys are lightweight and strong. They do not possess the corrosion resistance of pure aluminum and are generally treated to prevent deterioration.

"Alclad" is an aluminum alloy with a protective coating of aluminum to make it equal to the pure metal in corrosion resistance.

(1) In order to provide a visual means for identifying the various grades of aluminum and aluminum alloys procured and stored by the Army Air Forces, such metal is marked with symbols. The symbols used consist of the Government specification number and the temper or condition furnished, or the commercial code marking.

(*a*) The commercial code marking consists of a number which identifies the particular composition of the metal. A letter preceding the number indicates a modification of the alloy. In addition, letter suffixes designate the following:

S—Wrought.
O—Dead soft or fully annealed.
H—Fully cold-worked or hard-wrought fractions preceding letter indicate intermediate tempers, as ½H, ¾H.
W—Condition following solution treatment and prior to aging.
T—Fully heat-treated and aged.
RT—Temper resulting from cold-working after heat treatment and aging.

(*b*) All plates and sheets are marked with specification numbers or code markings in rows approximately 5 inches apart.

(*c*) Tubes, bars, rods, and extruded shapes are marked with specification numbers or code markings at intervals of 3 to 5 feet along the length of each piece. On material which is too small or which has a cross-sectional shape which does not permit marking with characters, a band of colored enamel, approximately 2 inches wide, is placed at each end and in the middle of the material. The color is in accordance with table IV.

(2) The aluminum and various aluminum alloys, in wrought form, used in aircraft construction are as follows:

(*a*) Aluminum designated by the symbol 2S is used where strength is not an important factor but where weight economy and noncorrodability are desirable. This aluminum is used for fuel tanks, cowling, oil tanks, and for the repair of wing tips and tanks.

(*b*) Alloy 3S is similar to 2S and is generally used for the same purposes. It contains a small percentage of manganese and is stronger and harder than 2S aluminum.

(*c*) Alloy 17S is used for stressed skin covering, extruded structural members, and rivets.

(*d*) Alloy 24S, plain and with Alclad coating, is used for heat-treated parts, airfoil covering, and fittings. It is stronger than alloy 17S and may be used wherever alloy 17S is specified.

(*e*) Alloy 25S is used extensively for propeller blades.

(*f*) Alloy 52S is used for fuel lines, hydraulic lines, fuel tanks, and wing tips.

(3) Cast aluminum alloys are used for cylinder heads, crankcases, fuel injectors, carburetors, and landing wheels.

(4) Various alloys, including 3S, 52S, and 2S aluminum, are hardened by cold-working and not by heat treatment. Others, including 17S and 24S, are hardened by heat treatment, cold-working, or a combination of both. Various casting alloys are hardened by heat treatment.

9. Magnesium alloys.—*a.* Magnesium alloys are the lightest of aircraft structural metals, weighing only approximately ⅔ as much as the aluminum alloys. The alloying elements consist generally of aluminum, manganese, and zinc. Because of their excellent strength-weight ratio, magnesium alloys are being used more extensively in aircraft construction, and may be obtained in wrought and cast forms. The wrought alloys are produced in sheets, plates, rods, bars, extruded shapes, wire, and forgings. The wrought alloys are used for framework of cockpit canopies and other secondary structural parts. The castings are used for miscellaneous fittings, landing wheels, engine crankcases, and housings for aircraft engine accessories.

b. The magnesium alloys are subject to corrosion in salt atmosphere. They are also subject to electrolytic corrosion and are insulated from contact with other metals. Corrosion is indicated by a powdered or roughened surface.

10. Copper and its alloys.—Copper in the commercial form is 99.9 percent free from impurities. It is extremely malleable and ductile. Copper is principally used in aircraft for electrical conductors and terminals, shielding, locking wire, instrument lines, and fuel and oil lines.

a. Brass in its simplest form is an alloy of copper and zinc, although other metallic elements are often added to improve its characteristics. Naval brass is one of these alloys. Brass is corrosion resistant, strong, tough, and wear resistant. It is widely used for tube fittings, drain cocks, screws, and nuts. Naval brass is used for turnbuckle barrels.

b. Bronze is essentially an alloy of copper and tin. However, various other elements are alloyed with copper to form the alloys commercially known as bronzes, and they are generally designated by the name of one of the alloying elements such as aluminum bronze, phosphor bronze, and manganese bronze. Bronze is highly corrosion resistant. A bronze consisting mainly of copper, equal percentages of tin, zinc, and lead, and small percentages of other elements is used for tube fittings in aircraft. Manganese bronze is also used for this purpose.

TABLE IV.—*Color markings for aluminum alloys*

Alluminum alloy No.	Specification	Color used
2	QQ-A-411	White.
	57-151-1	Do.
	WW-T-783	Do.
11	11330	Green.
17	QQ-A-351	Yellow.
	QQ-A-353	Do.
	57-152-2	Do.
	WW-T-786	Do.
	QQ-A-367 (grade 1)	Do.
24	QQ-A-354	Insignia red.
	10235	Do.
	QQ-A-367 (grade 5)	Do.
52	QQ-A-318	Purple.
	57-187-3	Do.
53	QQ-A-331	Black.

SECTION IV

NONMETALLIC MATERIALS

11. **General.**—Nonmetallic materials are used in the manufacture of articles such as control surfaces, tires, grommets, windshields, fiber wheels, finishes, etc. Constant research with nonmetallic materials has resulted in their substitution for metals in the manufacture of many articles of aircraft equipment. Recent developments in the field of plastics indicate the possibility of aircraft structural members constructed entirely of such materials.

12. **Fabric.**—*a.* A cotton fabric is used extensively for covering the surfaces of small, low-speed training type airplanes, and for covering flight control surfaces on high-speed types of airplanes.

b. This fabric is produced from long-staple cotton in a plain weave and free from nap. It is produced in various widths, the weights of which range from 4.0 to 4.5 ounces per square yard, depending upon the width, and it has a tensile strength of 80 pounds per inch of width in both the warp and filler threads.

c. Fabric used for aircraft surfaces is treated with nitrate dope after it is attached to the structure. This tends to shrink the fabric, producing a smooth, taut surface.

13. Plastics.—*a.* Plastics are substances capable of being molded or otherwise fabricated into a solid form. This characteristic is obtained by the physical and chemical interaction of a wide range of materials. Different types of plastics have varied properties. The materials in general have smooth surfaces which are not subject to rust, chipping, or denting. They are light and durable as well as tough. "Plastacele," "plexiglas," and "bakelite" are some of the commercial plastics used in aircraft construction.

b. Plastacele is a cellulose acetate plastic. It will ignite in an open flame but burns very slowly. Plastacele does not readily crack or discolor with age. It is used chiefly for windshields and cockpit inclosures on small airplanes.

c. (1) Plexiglas is a transparent plastic made from methyl methacrylate. It is supplied in large sheets ranging in thickness from 0.060 to 0.500 inch. Rods and square bar forms may also be obtained for special application.

(2) The abrasive resistance of plexiglas exceeds that of other plastics. It burns very slowly when subjected to an open flame, but otherwise it is not readily ignited. It does not discolor with age and is only slightly affected by sunlight, acids, etc. Although plexiglas does not possess the abrasive resistant qualities of glass, it excels other plastics in optical qualities, having a transparency of approximately 90 percent, which is equivalent to quartz in this respect.

(3) This plastic is used to advantage in airplanes for bombardier compartments, gun turrets, and formed windshield sections.

d. (1) The plastics usually referred to as bakelite are those containing synthetic resins of phenol or urea as a base. Phenolic is the term applied to resins composed chiefly of phenol and formaldehyde. A combination of urea and formaldehyde forms a resin which, in the raw or primary state, may be melted and is soluble in acetone, alcohol, or similar solvents. Heating and the application of pressure convert the resin into a plastic. After "setting," this plastic is infusible, insoluble, and chemically inert.

(2) Products of these resins are of two general types, laminated and molded. In the laminating process, sheets of paper or fabric are impregnated with the resin and placed in layers to obtain the desired thickness. These sheets are pressed while subjected to heat, which produces a hard, tough, smooth sheet plastic. In the molding process the resin is combined with a filler such as wood, asbestos, fabric, or paper and the mixture placed in a mold. The application of heat and pressure produces a molded plastic.

(3) Bakelite stock may be obtained in the form of sheets, tubes, or rods of various dimensions. Complete parts are manufactured by

the molding process while the sheet, tube, and rod stock may be cut, machined, or punched as desired.

(4) The properties of bakelite products depend, in general, upon the percentage of resinoid employed and the type of laminating sheet or filler selected. The resin produces a smooth, lustrous surface while providing a strong, tough bonding agent. Laminated bakelite is stronger than the molded form. The resinoid employed in bakelite is an effective organic dielectric, thus making it especially desirable for the manufacture of electric equipment such as control panels, magneto distributors, etc. This plastic may be subjected to temperatures of 300° F. without distortion or charring and will withstand water, oil, mild acids, or common solvents.

14. Safety glass.—Safety glass, also termed nonshatterable glass, consists of two pieces of sheet or plate glass firmly cemented to a transparent sheet plastic. This construction produces a stronger sheet than ordinary glass, and is highly desirable from the standpoint of safety. The plastic sheet adheres to the glass and prevents it from shattering under impact. Safety glass is manufactured in standard flat sheet form of varying thickness, ranging from 1/8 to 1/2 inch. It is used for windshields, windows, and door glass when forming is not required.

15. Natural rubber.—*a.* Natural commercial rubber is obtained by processing the milky juice (latex) obtained from certain tropical trees. Prior to shipment from the plantations the latex is coagulated by smoking or combining with acetic acid. The result is sticky coagulant which is dried and shipped in thin crinkled sheets. In order to increase the useful properties, crude rubber is mixed with various materials including reinforcing pigment (gas black, zinc oxide), softeners (paraffin, oils, tars), vulcanizing agents (sulfur, sulfur monochloride), and age resistors.

b. Rubber is available in several forms and varying degrees of hardness as designated by "Shore durometer" hardness numbers. Pure gum rubber, hardness numbers 25 to 35, is available in sheet form, channel sections, and tubing. A medium-soft black molded rubber, hardness numbers 40 to 55, may be obtained in sheet and various extruded sections. Sheet, molded, and extruded sections are also manufactured from a medium hard rubber, hardness numbers 55 to 70. Molded equipment is produced from hard rubber. Shore numbers 70 to 90. Sponge rubber is produced in three grades: hard, medium, and firm.

c. Rubber is resistant to abrasive wear, flexible, elastic, waterproof, relatively permeable to gases, and has high friction against a dry surface. It is a satisfactory heat and electric insulator and resists

the action of many chemical agents. It deteriorates under the action of oils, gasolines, etc., and is affected by flames and temperatures exceeding 200° F.

d. Narrow lengths of sponge rubber are used for weatherstripping doors, while the sheet form is applicable to certain shock absorption mountings. Pure gum rubber is used for glass channels, bumpers, washers, gaskets, etc. A medium hard rubber is used for extruded sections and moldings where hardness and wear resistance are necessary. Hard rubber is used in stiff heavy-duty bumpers. Other applications of rubber in aircraft include tires and tubes for landing wheels, shock cord, molded engine shock mounts, grommets, floor matting, insulating tape, hose, tubing and other special uses.

16. Synthetic rubber.—*a.* Synthetic rubber is produced under various trade names such as Neoprene, Thiokol, Hycar, Chemigum, Perbuman, etc. Neoprene, for example, is manufactured from coal, limestone, and salt. Like natural rubber, synthetic rubber is mixed with other compounds to increase its useful properties.

b. Synthetic rubber materials are produced in forms similar to the natural rubber. The process of manufacture is also similar. It has a high stability and resistance to deterioration, exceeding that of the natural product, and other properties comparable to natural rubber. Whereas rubber swells and loses strength, toughness, and elasticity when exposed to oils, gasolines, naphtha, etc., synthetic rubber remains unaffected. Natural rubber cracks and deteriorates rapidly when exposed to direct sunlight, while synthetic rubber is not affected. Resistance to heat is notable in synthetic rubber, especially at temperatures between 180° F. and 300° F. The effect of heat is to soften natural rubber, while synthetic rubber becomes hard and eventually brittle. Synthetic rubber is less subject to natural deterioration from oxidation and consequently excels the natural product.

c. Synthetic rubber has numerous applications in aircraft and due to superior characteristics is rapidly replacing natural rubber. It is now used for hose connections in oil and fuel lines and for engine shock mounts. Gaskets and packings subjected to oils and hydraulic fluids are also made from synthetic rubber. It can be used to advantage in parts operating under continuous temperatures of 300° F. or above. Synthetic rubber has been successfully used as a lining for gasoline tanks, thus providing, in combination with other materials, a leakproof tank.

17. Wood.—*a.* The present use of wood is limited to the lighter weight types of airplanes, such as the training and reconnaisance types, and to gliders. Some woods have high strength-weight ratios

which compare favorably with those of metal. Spruce is one of the principal aircraft woods. It is light in weight, straight-grained and moderately strong, and has an excellent strength-weight ratio. Other woods used are ash, birch, cedar, Douglas fir, mahogany, maple, pine, and oak. The strength of wood is affected by knots, direction of grain, moisture, decay, etc., therefore, careful selection of lumber for the manufacture or repair of aircraft parts is very important. Wood is used for ribs, fairing strips, solid spars, and miscellaneous interior fittings.

b. Plywood consists of thin layers of wood veneer glued together with the grain of adjacent layers at right angles to each other. This type of construction increases the mechanical properties of wood, giving an approximate equality of properties in two directions, namely, parallel and perpendicular to the edge of the board. Hard woods are used for the faces and softer woods for the core. Plywood is used in the fabrication of parts such as box spar facings, wing rib webs, covering for leading edges, and interior fittings.

c. Laminated wood consists of two or more pieces of wood properly glued together with their grains running approximately parallel. The lamination of wood reduces warpage, increases strength, and facilitates forming into special shapes. Propellers, wing spars, and wing tips for some types of airplanes are constructed of laminated wood.

SECTION V

PROTECTIVE COATINGS AND FINISHES

18. General.—*a*. (1) Protective coatings and finishes are applied primarily for the purpose of protecting surfaces exposed to destructive elements, such as moisture, sunlight, salt spray, heat, cold, etc. Metal is subject to rusting or other corrosive action, wood is subject to cracking, checking, warping, and the action of fungoid growth, while fabric loses its strength due to deterioration. Color is a secondary purpose of finishes.

(2) Corrosion of metals is a chemical process resulting in the internal destruction or eating away of the surface. Rusting of iron and pitting of aluminum alloys are two common examples of corrosion. Corrosion is generally an electrochemical process occurring between the base metal and the remaining elements in the alloy. Internal corrosion, called intercrystalline corrosion, is particularly treacherous, since it progresses beneath the surface of the metal sometimes with no obvious outward indication of its presence. Corrosion of this type may start from a scratch or nick in the protective coating, thus permitting exposure of the metal to the moisture of the atmosphere. Salt spray is especially corrosive and metals thus exposed require special protection. Surface corrosion, such as rusting, may be prevented by cleaning the surface thoroughly and applying a protective coating of rust-resisting metal primer, varnish, enamel, or lacquer. Internal or intercrystalline corrosion may be prevented by correct heat treatment of the metal or modification of the alloy.

(3) Corrosion may also occur as a result of electrical action between two dissimilar metals in contact, especially in the presence of moisture or salt spray. The action is similar to that of an electric cell and results in the destruction of one or more of the metals, just as the zinc electrode of a primary cell is disintegrated by the electrical action of the cell. Consequently, when two dissimilar metals are bolted or otherwise fastened together, the contacting surfaces are insulated and/or plated to prevent corrosion. For example, steel in contact with aluminum or copper alloys is cadmium-plated and then insulated with two coats of finishing material to prevent corrosion. All joints, regardless of the metals involved, are insulated if they are subject to submersion or exposure to water.

b. The two general classes of protective coatings and finishes used for aircraft are metallic and nonmetallic.

(1) Metallic coatings and finishes employ either the application of a thin layer of a pure metal having high corrosion-resisting qualities to the surface of the metal involved or chemical or electrochemical treatment of the metal surface.

(2) Nonmetallic coatings and finishes employ the application of one or more coats of primer, dope, varnish, enamel, or lacquer to the surface involved. These are loosely referred to as paints.

(*a*) There are three general classes of nonmetallic finishes: oil base, pyroxylin base, and synthetic materials. The first group utilizes a linseed oil composition and includes flat and gloss paints, varnish, and enamel. Pyroxylin finishes include lacquers and dopes. They contain a cellulose base and dry rapidly. Synthetic finishes contain a synthetic gum or plastic base and include various enamels and

primers. Enamels of this type are somewhat slower drying than pyroxylin materials. Synthetic primers, however, dry rapidly.

(*b*) Care should be exercised in using these three types of finishes in combination. As a general rule, pyroxylin finishes cannot be applied over oil-base materials because the action of the solvents tends to soften and remove the varnish or enamel from the surface.

(*c*) Finished surfaces on wood or metal over which fabric is to be placed are generally given a coating of dopeproof paint, unless one or more coats of zinc chromate primer have been applied previously. This is to prevent the solvents in the dope from affecting the other finishes.

19. Plating.—*a.* Plating is the process of applying a metallic protective coating to metal by an electrochemical process. The part to be plated is immersed in a solution of a salt of the plating metal. A direct electric current is passed through the solution from a pure plate or bar of the plating metal to the part being plated; by this process, the plating metal is transferred to and deposited evenly upon the part.

b. The common plating metals are cadmium, chromium, nickel, and copper. Cadmium is a soft, ductile, highly corrosion-resistant metal which is widely used as a plating element in aircraft construction. It will not withstand abrasion, but a thin coating is sufficient to produce a highly corrosive-resistant surface. Where high luster, hardness, resistance to tarnish, abrasion, and corrosion are desirable, chromium is applied. Chromium produces a hard, lustrous surface but has only minor applications in aircraft construction, such as interior fittings. Nickel or copper is generally applied as a base plate for chromium.

c. Plating is usually applied to parts not inherently resistant to corrosion. Steel bolts, nuts, turnbuckles, clevises, small welded parts, etc., are cadmium-plated.

20. Metalizing.—*a.* Metalizing is a process of spraying molten metal over the surface of a part to be finished. In aircraft work, cadmium and aluminum are generally used in this process to coat steel and other metals to improve their corrosion resistance. This process is employed to advantage where electroplating is impractical or impossible.

b. The surface to be metalized is prepared by sand blasting to roughen it and to remove all oxide and scale. The metal coating material in the form of wire is fed into a torch which instantly melts it. An air blast, piped to the nozzle, strikes the molten metal, atomizes it, and drives it onto the part to be metalized.

21. Anodic treatment.—Aluminum and aluminum alloy parts, except Alclad parts, receive the anodic treatment as a protection against corrosion and also to provide a bonding surface for subsequent finishes. Anodizing is an oxidation process accomplished by immersing the parts to be treated in a chromic or sulfuric acid solution and passing an electric current from the part through the solution to the metal container. This produces an aluminum oxide film which is corrosion resistant. The anodic film is very thin and care must be exercised to avoid scratches or abrasions. Anodic treatment is not a plating process.

22. Primers.—*a.* Primers serve several purposes in the finishing process. When applied to wood the first or prime coat acts as a filler to seal the grain. A special primer is applied to metal to provide a bond between the metal and subsequent finishes. Primers usually dry a dull flat. This type of surface provides better adherence for finishes than is obtained with a smooth shiny surface.

b. Zinc chromate is used as a metal primer in aircraft finishing. Zinc chromate primer consists of zinc chromate and a synthetic gum or plastic base. It is a satisfactory agent for preventing corrosion of aluminum alloys and is equally adaptable to all aircraft metals. Zinc chromate dries rapidly and subsequent finishes may be applied within 20 minutes.

c. Primers are generally applied by spraying or dipping, which provides uniformity and appearance not obtained by other methods. Brushing is usually confined to touching-up operations where facilities for spraying are not available.

23. Dope.—*a.* The basic constituent of dope is cellulose nitrate, with a plasticizer, solvents, and thinner added. The plasticizer prevents hardening and cracking of the nitrate base, thus providing a flexible film. The usual solvents are esters or ketones such as ethyl acetate and butyl and methyl ethylketone acetate, while thinners consist of alcohol, aromatic hydrocarbons, and petroleum distillates.

b. Dope is a rapid drying material which is applied to fabric aircraft surfaces. The first few coats tend to shrink the fabric, producing a smooth, taut surface. The remaining coats produce the color scheme desired and serve as a protection against the ultraviolet rays of the sun, which are detrimental to the strength of the fabric. A sufficient number of correctly applied coats of dope will produce a smooth, waterproof, and airproof surface.

c. The first coat of dope is applied with a brush to saturate the fabric thoroughly. The remaining coats are applied by spraying to obtain uniformity and smoothness.

24. Varnish.—Varnish consists of gums or resins dissolved in vegetable oils and thinned to the proper consistency by volatile thinners. Varnish dries through the oxidation of the oil and the evaporation of the volatile solvents. Aircraft varnishes are produced from synthetic resins such as glyceryl phthalates and phenol-formaldehyde, and may be classified as air drying or baking types. They are used as a protective finish for wood and metal.

25. Enamel.—Enamel is similar to varnish except that it contains an opaque pigment for coloring. It produces a very hard, smooth surface; however, its application to aircraft is limited to special purposes. Certain types of engine cylinders and other equipment which must withstand high temperatures are finished in baked enamel. Instrument panels are finished with a lusterless enamel which is sometimes baked.

26. Lacquer.—Lacquer is a pyroxylin base material. The body of lacquer consists of nitrocellulose in solution with volatile solvents. Pigment is added to provide opacity or coloring. Lacquer is used extensively for finishing all types of surfaces. It may be applied by spraying or with a brush and dries very rapidly, thus permitting the application of a number of coats in a relatively short time.

SECTION VI

AIRCRAFT HARDWARE

27. General.—*a.* Aircraft hardware may be considered as that group of parts consisting of bolts, nuts, rivets, pipe fittings, terminals, etc., which is applicable to and interchangeable on all types of military aircraft. The application of these parts is extensive. Apparently dwarfed in importance because of their small size, nevertheless the safe and efficient operation of the aircraft is based upon these parts.

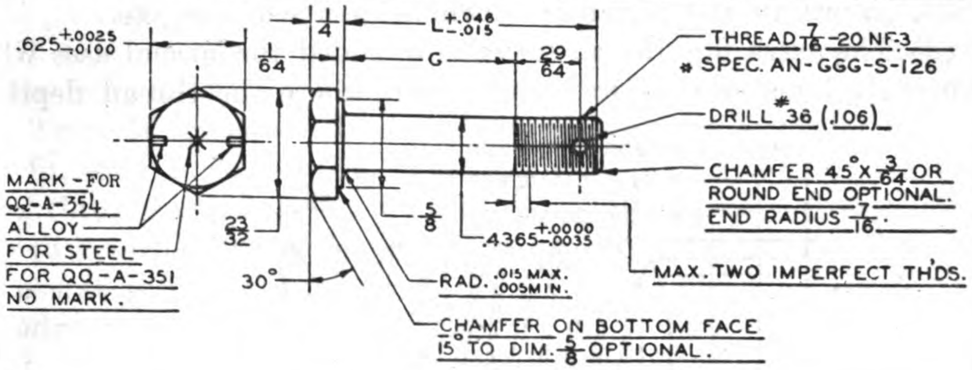
b. A damaged part may result in destruction of the aircraft and loss of life; therefore, during assembly or disassembly, extreme care must be exercised, and only such tools as are intended for each part should be used. The proper functions of the various parts depend to a large extent upon their material strength and careful fitting; therefore when replacements are made, a part of identical material and size should be used.

c. Dimensional and other data pertaining to specific parts are contained in the Air Corps Standards Book, which is a tabulation of such parts as the Army Air Forces has selected as standard for aircraft construction. This publication is distributed to Army Air Forces activities for information and guidance in connection with the classification, identification, and inspection of property. The parts listed in this publication are not all carried in Army Air Forces stock but have been included to meet possible future demands in the development of aircraft and aircraft equipment. Inasmuch as only such parts as are necessary for the maintenance of existing aircraft are ordinarily carried in Army Air Forces stock, when ordering supplies the Army Air Forces Stock List must be consulted.

d. Parts are numbered by a simple method in the Air Corps Standards Book. A representative page from the book, on a hexagonal-headed aircraft bolt, is shown in figure 2. This bolt is listed under part numbers AN3 to AN16, inclusive. The prefix AN denotes that the part has been standardized by both the Army and the Navy to be used interchangeably by either. For this particular bolt, the numeral following the AN indicates the bolt diameter in sixteenths of an inch; thus, AN7 refers to this type of bolt with a diameter of $\frac{7}{16}$ inch. However, the complete description of this bolt with respect to size is yet lacking; therefore, a dash number is added which indicates the length of the bolt in eighths of an inch. Accordingly, AN7-7 refers to this type of bolt with $\frac{7}{16}$ inch diameter and $\frac{7}{8}$ inch length. For dash numbers of 10 and above, the first digit indicates full inches and the second digit eights of an inch; thus, dash number 10 indicates 1 inch$+\frac{0}{8}$ inch$=$1 inch; dash number 22 indicates 2 inches$+\frac{2}{8}$ inch$=$2 inches$+\frac{1}{4}$ inch$=2\frac{1}{4}$ inches; dash number 35 indicates 3 inches$+\frac{5}{8}$ inch$=3\frac{5}{8}$ inches, etc. It is to be noted that sheet number AN7 is merely representative; other sheet numbers up to and including AN16 give other sizes, and related values which may vary. The part number also indicates the kind of material used; thus, AN7-6 refers to a steel bolt and AN7DD6 refers to an aluminum alloy bolt. The letter A added to a part number is used to designate this bolt without cotter pin hole for use with self-locking nut, as AN7-6A (steel) and AN7DD6A (aluminum alloy).

28. Screw threads.—*a.* Numerous items of aircraft hardware are threaded. A screw thread may be defined as a continuous helical ridge of uniform section on the external or internal surface of a cylinder or cone. The more common forms of screw threads (fig. 3)

U. S. ARMY AIR CORPS, MATERIEL DIVISION, DAYTON, OHIO



DASH NOS.	L'GTH	G	DASH NOS.	L'GTH	G	DASH NOS.	L'GTH	G	DASH NOS.	L'GTH	G
			22	2 1/4	1 11/16	42	4 1/4	3 11/16	62	6 1/4	5 11/16
			23	2 3/8	1 13/16	43	4 3/8	3 13/16	63	6 3/8	5 13/16
			24	2 1/2	1 15/16	44	4 1/2	3 15/16	64	6 1/2	5 15/16
5	5/8	1/16	25	2 5/8	2 1/16	45	4 5/8	4 1/16	65	6 5/8	6 1/16
6	3/4	3/16	26	2 3/4	2 3/16	46	4 3/4	4 3/16	66	6 3/4	6 3/16
7	7/8	5/16	27	2 7/8	2 5/16	47	4 7/8	4 5/16	67	6 7/8	6 5/16
10	1	7/16	30	3	2 7/16	50	5	4 7/16	70	7	6 7/16
11	1 1/8	9/16	31	3 1/8	2 9/16	51	5 1/8	4 9/16	71	7 1/8	6 9/16
12	1 1/4	11/16	32	3 1/4	2 11/16	52	5 1/4	4 11/16	72	7 1/4	6 11/16
13	1 3/8	13/16	33	3 3/8	2 13/16	53	5 3/8	4 13/16	73	7 3/8	6 13/16
14	1 1/2	15/16	34	3 1/2	2 15/16	54	5 1/2	4 15/16	74	7 1/2	6 15/16
15	1 5/8	1 1/16	35	3 5/8	3 1/16	55	5 5/8	5 1/16	75	7 5/8	7 1/16
16	1 3/4	1 3/16	36	3 3/4	3 3/16	56	5 3/4	5 3/16	76	7 3/4	7 3/16
17	1 7/8	1 5/16	37	3 7/8	3 5/16	57	5 7/8	5 5/16	77	7 7/8	7 5/16
20	2	1 7/16	40	4	3 7/16	60	6	5 7/16	80	8	7 7/16
21	2 1/8	1 9/16	41	4 1/8	3 9/16	61	6 1/8	5 9/16			

ENGINEERING INFORMATION

MATERIAL	STAND. PLAIN NUT		STAND. CASTLE NUT COTTER PIN AN380-3-3		TEN. STR. AT ROOT DIA.	YIELD STR. AT ROOT DIA.	* SINGLE SHEAR FULL DIA.
STEEL	AN315-7R	MAX. GRIP =G +7/32	AN310-7	MAX. GRIP = G + 9/64	13430#	10740#	11270#
ALUM. AL. QQ-A-354	AN315D7R		AN310D7		6660#	4290#	5260#
ALUM. AL. QQ-A-351					5910#	3220#	4500#

EXAMPLE OF PART NO. - AN7-6 = BOLT - STEEL
AN7D6 = BOLT - ALUM. ALLOY (QQ-A-351)
* AN7DD6 = BOLT - ALUM. ALLOY (QQ-A-354)
ADD "A" TO PART NUMBERS TO DESIGNATE BOLTS WITHOUT COTTER PIN HOLES AS AN7-6A, AN7D6A, AN7DD6A

NOTE - BOLTS OF QQ-A-351 INACTIVE FOR DESIGN AND PROCUREMENT

SPECIFICATION 29-59
LIMITS ON DIMENSIONS ±.010 UNLESS OTHERWISE SPECIFIED B/M

APPROVED	AIR CORPS STOCK CLASSIFICATION 04A	ARMY & NAVY STD.
3-22-26	BOLT - AIRCRAFT - 7/16-20	AN 7

REVISED 3-2-36, 11-20-36, 12-12-38, 8-25-41

FIGURE 2.—Representative page from Air Corps Standards Book.

are known as national coarse series, national fine series, national extra fine series, and American national taper pipe thread.

(1) The coarse thread series is intended for use in soft metals and in designs where the characteristic of rapid engagement is desirable.

(2) The fine thread series is intended for general use in aircraft and engine construction; it is widely applied to fastenings, such as bolts, screws, tie-rod terminals, turnbuckle assemblies, etc.

(3) The extra fine thread series is intended for special uses where thin-walled material is to be threaded, where the thread depth of

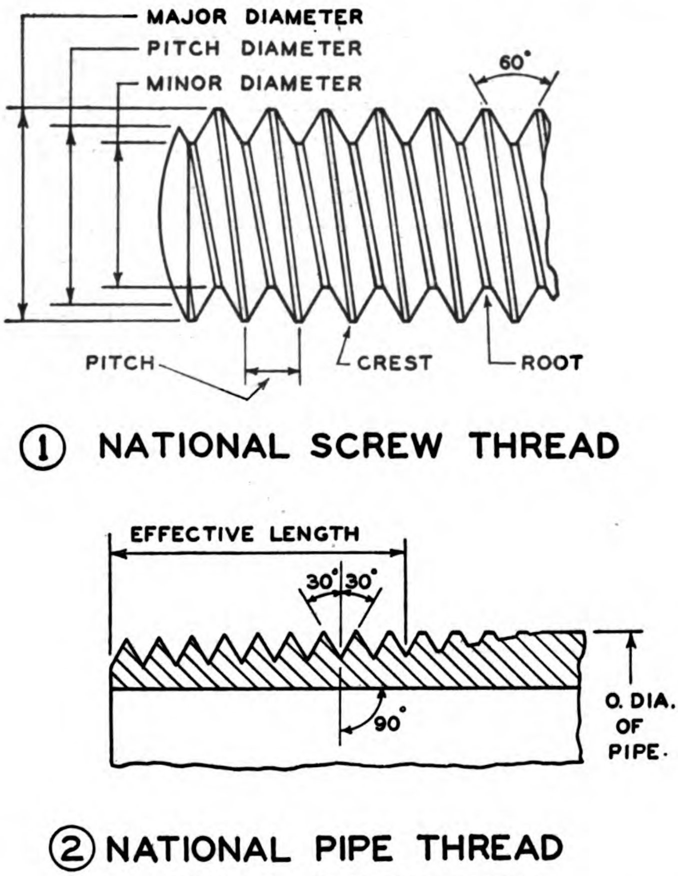


FIGURE 3.—Screw thread forms.

nuts clearing ferrules, coupling flanges, etc., must be held to a minimum, and where a maximum possible number of threads are required within a given thread length.

(4) The pipe thread is intended for use on taper-threaded pipe joints; the taper feature (¾ inch per foot) permits a tighter fit with continued engagement of the screw thread.

b. Screw threads are also classified according to "fit."

(1) Class 1 (loose fit) includes screw threads used for work where clearance between the mating parts is essential for rapid assembly and where shake or play is not objectionable.

(2) Class 2 (free fit) is intended for parts which mate with commercial parts such as machine screws, nuts, etc., where a moderate amount of shake and play between the assembled thread members is not objectionable.

(3) Class 3 (medium fit) is intended for parts where a minimum amount of shake or play between threaded parts is desirable. This fit is generally employed in aircraft construction.

(4) Class 4 (close fit) is intended to meet very unusual requirements, more exacting than those for which class 3 is intended.

c. Threads are generally designated by symbols according to type and fit, such as NF–3 (National fine, medium fit); right- and left-hand threads are designated by R H and L H, respectively. Sizes (up to 1 inch), corresponding diameters, and threads per inch for the coarse and fine thread series are given in table V. Data on pipe threads are given in table VI.

29. Bolts.—A bolt is used in conjunction with a nut (except where used in tapped hole) to fasten together component parts of a mechanism or structure. Standard aircraft bolts are marked for identification. The head of a steel bolt is marked with an asterisk (*) or X, and an aluminum alloy bolt bears two opposed U-marks on the head. No steel bolt smaller than number 10 and no aluminum bolt smaller than ¼ inch is used in the primary structure of the aircraft. Bolts

TABLE V.—*American national screw thread series*

National fine thread series, class 3 fit				Screw size	National coarse thread series, class 3 fit			
Tap drill size	Hole diameter (inches)	Body diameter (inches)	Threads per inch		Threads per inch	Body diameter (inches)	Hole diameter (inches)	Tap drill size
3/64 inch	0.0465	0.060	80	No. 0				
No. 53	.0580	.073	72	No. 1	64	0.073	0.0561	No. 53.
No. 50	.0691	.086	64	No. 2	56	.086	.0667	No. 50.
No. 46	.0797	.099	56	No. 3	48	.099	.0764	5/64 inch.
No. 42	.0894	.112	48	No. 4	40	.112	.0849	No. 44.
No. 38	.1004	.125	44	No. 5	40	.125	.0979	No. 39.
No. 34	.1109	.138	40	No. 6	32	.138	.1042	No. 36.
No. 29	.1339	.164	36	No. 8	32	.164	.1302	No. 29.
No. 22	.1562	.190	32	No. 10	24	.190	.1449	No. 26.
No. 15	.1794	.216	28	No. 12	24	.216	.1733	No. 17.
No. 3	.2113	.250	28	¼ inch	20	.250	.1959	No. 8.
I	.2674	.3125	24	5/16 inch	18	.3125	.2524	F.
Q	.3299	.375	24	⅜ inch	16	.375	.3073	5/16 inch.
W	.3834	.4375	20	7/16 inch	14	.4375	.3602	U.
29/64 inch	.4459	.500	20	½ inch	13	.500	.4167	27/64 inch.
0.5062 inch	.5024	.5625	18	9/16 inch	12	.5625	.4723	31/63 inch.
0.5709 inch	.5649	.625	18	⅝ inch	11	.625	.5266	17/32 inch.
11/16 inch	.6823	.750	16	¾ inch	10	.750	.6417	0.6496.
51/64 inch	.7977	.875	14	⅞ inch	9	.875	.7547	49/64 inch.
0.9252 inch	.9227	1.000	14	1 inch	8	1.000	.8718	⅞ inch.

TABLE VI.—*American national taper pipe thread*

Nominal size of pipe (inches)	Threads per inch	Outside diameter of pipe (inches)		Pipe reamer size (inches)
		Decimal	Nearest common fraction	
1/8	27	0.405	13/32	0.327
1/4	18	.540	35/64	.4225
3/8	18	.675	43/64	.5572
1/2	14	.840	27/32	.6879
3/4	14	1.050	1 3/64	.8972
1	11 1/2	1.315	1 5/16	1.1278
1 1/4	11 1/2	1.660	1 21/32	1.4714
1 1/2	11 1/2	1.900	1 29/32	1.7103

(except the drilled head aircraft bolt) may be obtained with or without a hole for a cotter pin, being used in the latter instance with a self-locking nut or plain nut properly safetied.

a. The aircraft bolt (fig. 2) is used extensively throughout the aircraft as a means of fastening for parts of mechanisms, on mountings, etc. This type of bolt is available in steel or aluminum alloy.

b. The clevis bolt (fig. 4 ①) is generally used in installations where it is subjected to a shearing stress. Examples of its use are shown in figures 4 and 9. The head of the bolt is slotted to accommodate a screw driver. The clevis bolt is made of steel.

c. The head of the eye bolt (fig. 4 ②) is used as a means of attachment for such devices as the fork end of a turnbuckle assembly on wing flap linkage (fig. 4 ③); clevis on support for oil temperature regulator (fig. 4 ④); and cable shackle (fig. 9 ⑭). The bolt is made of steel.

d. The drilled head aircraft bolt (fig. 4 ⑤) is made of steel and is used as a means of anchorage to tapped parts or fittings. An example of its use is for attachment of supercharger cooling cap assembly to exhaust manifold (fig. 4 ⑥). The head of the bolt is drilled to receive locking wire for "safetying."

30. Screws.—The screw is a common form of threaded fastening device. It is usually described in accordance with the shape of its head. Screws are made of steel, aluminum alloy, or brass, depending upon the use for which the screw is intended. In figure 5 are shown various types of screws used in aircraft construction and equipment.

a. A machine screw (fig. 5 ①) is designed to be threaded into a tapped hole or used in conjunction with a nut. It is generally used for attachment of cover plates, fuselage panels, etc. Distinguishing features of some types of machine screws are as follows:

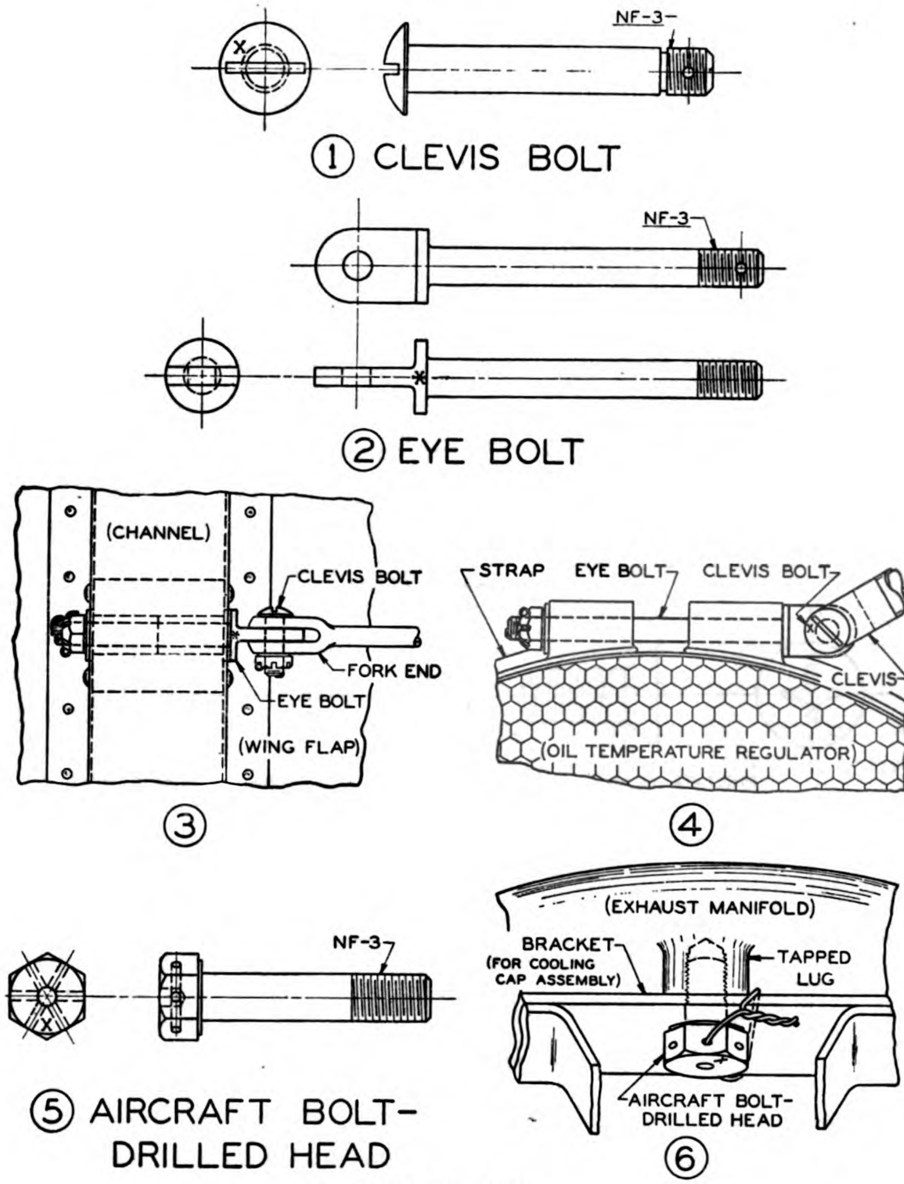


FIGURE 4.—Bolts.

(1) The fillister head screw is commonly used in light mechanism assemblies; it is available with or without drilled head.

(2) The flat head screw is used in countersunk holes, thus providing a surface free from projections, as is desirable in streamlining.

(3) The round head, button head, and washer head screws are used where head projections are not objectionable. Button head and washer head screws offer less resistance to airflow than does the round head type; the washer head type provides a large contact area.

(4) Phillips and Reed & Prince screws are of the cross-slot type and each requires a special screw driver (which has corresponding name).

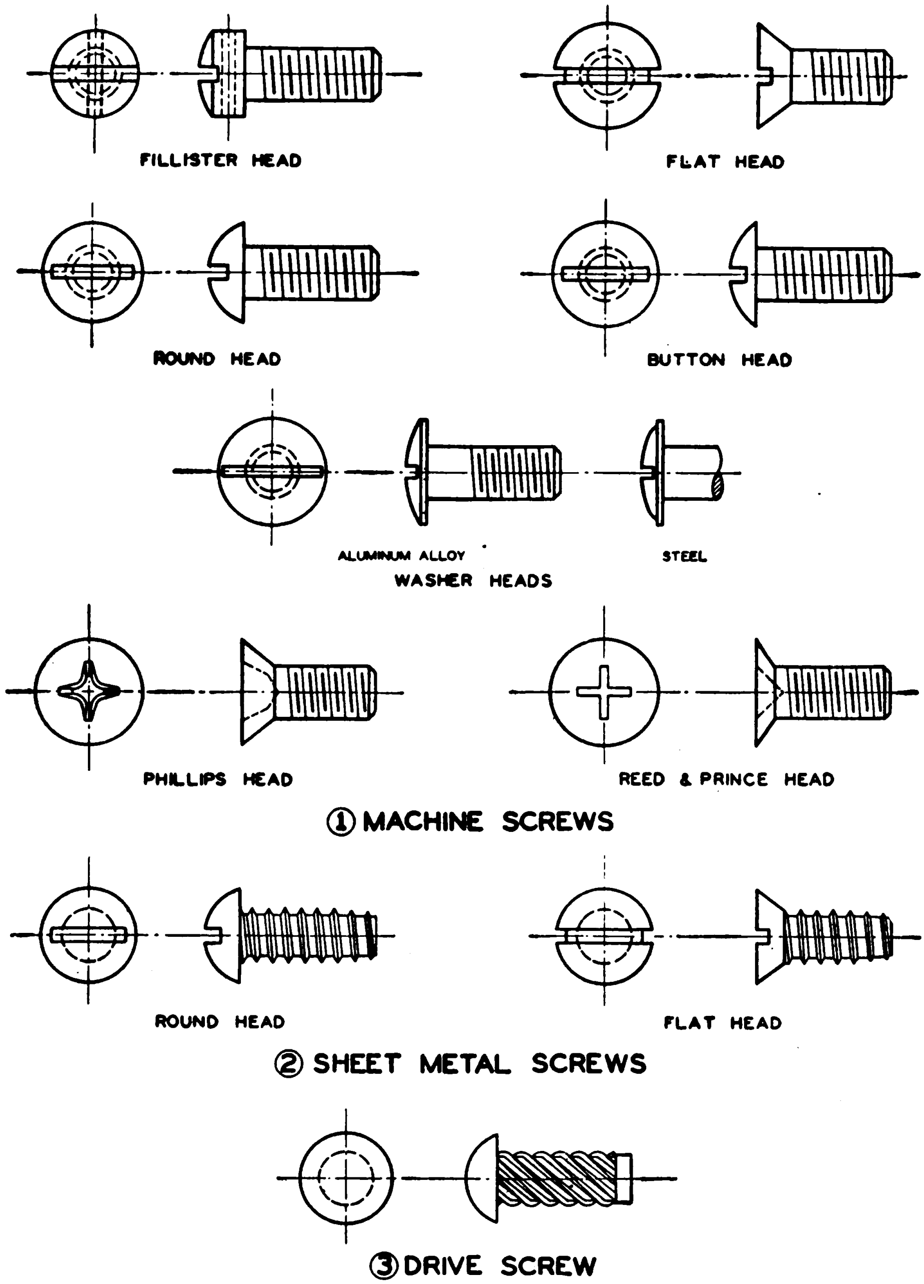


FIGURE 5.—Screws.

The cross-slot screw head will withstand more torsional stress than will the head of a single-slot screw.

b. Sheet metal screws (fig. 5 ②) are made of hardened steel and may be threaded directly into holes which are drilled or punched in sheet metal; thus, the tapping of the hole, or use of a nut, is eliminated. The self-threading feature is advantageous in installations which are accessible from only one side. The flat head type is used where flush installations are required.

c. The drive screw (fig. 5 ③) is made of hardened steel and is designed to be driven into an untapped hole slightly smaller in diameter than the screw. Spiral grooves are cut into the metal by the screw as it is driven into the hole. These grooves conform to and fit tightly with the threads on the screw. The drive screw is mainly used for such purposes as plugging holes and attaching name plates.

31. Nuts.—A nut is threaded internally to mate with the threads of a bolt, screw, or stud. It is essential that the threads of the nut conform to those on the bolt, otherwise jammed or stripped threads will result. Except in special applications, nuts used in aircraft are hexagonal in form. Nuts are made of steel, aluminum alloy, or brass, depending upon the use for which intended. Various types of nuts are shown in figure 6.

a. The plain aircraft nut (fig. 6 ①) is used to a very limited extent on aircraft structures and requires an auxiliary locking or "safetying" device such as a check nut or lock washer.

b. The check nut (fig. 6 ③) is used as a locking device for plain nuts, set screws, threaded rod ends, and other devices.

c. The aircraft castle nut (fig. 6 ④) is used in conjunction with a drilled end bolt or stud, and is designed to accommodate a cotter pin or lockwire as a means of safetying. The multiple slot arrangement permits proper adjustment of tension with correct alinement of slot and hole. The castellation portion of the nut is rounded or chamfered to conserve weight.

d. The shear nut (fig. 6 ⑤) has approximately three complete threads below the castellations and is designed for use with devices such as clevis bolts and taper pins, which are normally subjected to shearing stress and not tension.

e. The plain and slotted engine nuts (fig. 6 ② and ⑥) are high strength nuts not easily deformed by wrenches; they are designed specifically for use on engines where nuts receive more abuse than on aircraft structures. Both nuts require auxiliary locking devices.

f. The lock nut (fig. 6 ⑦), commercially known as the "Palnut," is used as a locking device for all external (never internal) engine nuts except those intended to be safetied with cotter pins or other locking devices; the lock nut is not used on bolts which do not protrude sufficiently to permit the full threaded length of the lock nut to engage. Lock nuts are available for use on bolts with coarse or fine threads.

g. The wing nut (fig. 6 ⑧) is intended for use where the desired tightness is ordinarily obtained by use of the fingers. The wing nut is used on hose clamps and battery terminal connections.

h. The coupling nut (fig. 6 ⑨) is used in conjunction with conduit couplings when joining sections of conduit, or conduit to a junction box (fig. 22 ⑤).

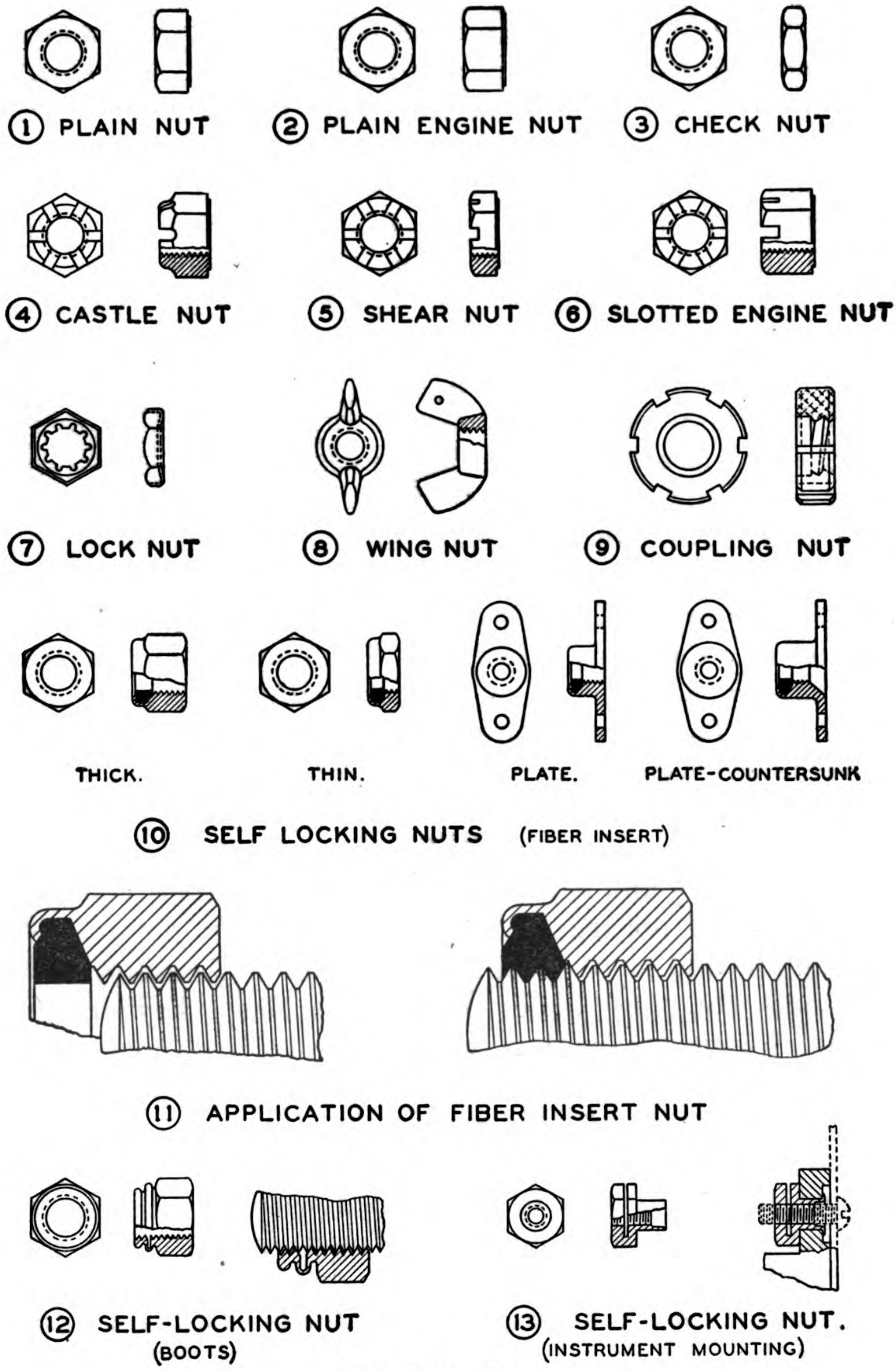


FIGURE 6.—Nuts.

i. (1) Nuts having locking devices embodied in their design are commonly referred to as self-locking nuts. Several types are in general use: the fiber insert (elastic stop) nut, spring member (boots)

nut, and instrument mounting nut. A self-locking nut is subject to the following limitations of usage:

(*a*) It should not be used at joints in control systems or aircraft structures where the nut would be subjected to a rotational movement in relation to the bolt.

(*b*) A nut containing a fiber or other nonmetallic insert should not be used where it would be subjected to a temperature in excess of 250° F. (121° C.).

(*c*) Round or chamfered end bolts or screws should extend through the nut for at least the full round or chamfer. Flat end bolts or screws should extend at least 1/32 inch through the nut.

(2) Fiber insert self-locking nuts are shown in fig. 6 ⑩. The fiber insert is made an integral part of the nut, but is not threaded. The inside diameter of the fiber insert is slightly less than that of the threaded section. When the nut is applied to the threaded portion of the bolt (fig. 6 ⑪), the fiber insert exerts pressure against the bolt in the direction of the bolt head, and consequently the threads of the nut and bolt are forced together as shown. The pressure holding the threads in close contact remains applied during and after the impression of threads in the fiber insert. The thick and thin nuts are used where specified, in the manner of ordinary nuts, whereas the plate nut is designed to be permanently attached to an assembly, usually structural members, in places accessible from only one side. The plate nut is affixed by rivets or screws. With the use of the plate nut such parts as wing tips and fuselage panels may be conveniently attached or removed from the outside of the aircraft. The countersunk plate nut is used with flat head screw to provide a flush surface.

(3) The outer section of the spring member (boots) type of self-locking nut (fig. 6 ⑫) is displaced toward the inner section. When the nut is threaded onto a bolt, the outer section is pushed away from the inner section and the spring action provided by the steel bellows keeps the nut under constant tension and prevents it from becoming loose. This type of self-locking nut is used as a fastening device on engine equipment where the temperature encountered would prohibit the use of a fiber insert nut.

(4) The self-locking nut shown in fig. 6 ⑬ is designed for use on instrument mountings. It is permanently attached to the instrument case to facilitate installation and removal of instruments. The slit in the nut provides a means of slightly bending the outer section of the nut toward the inner section. The screw forces the outer section of the nut away from the inner section to provide the tension which prevents loosening.

32. Rivets.—A rivet (fig. 7) is intended for use as a fastening device of a permanent nature. It is secured in place either by upsetting the end of the shank or by forming a complete rivet head. This

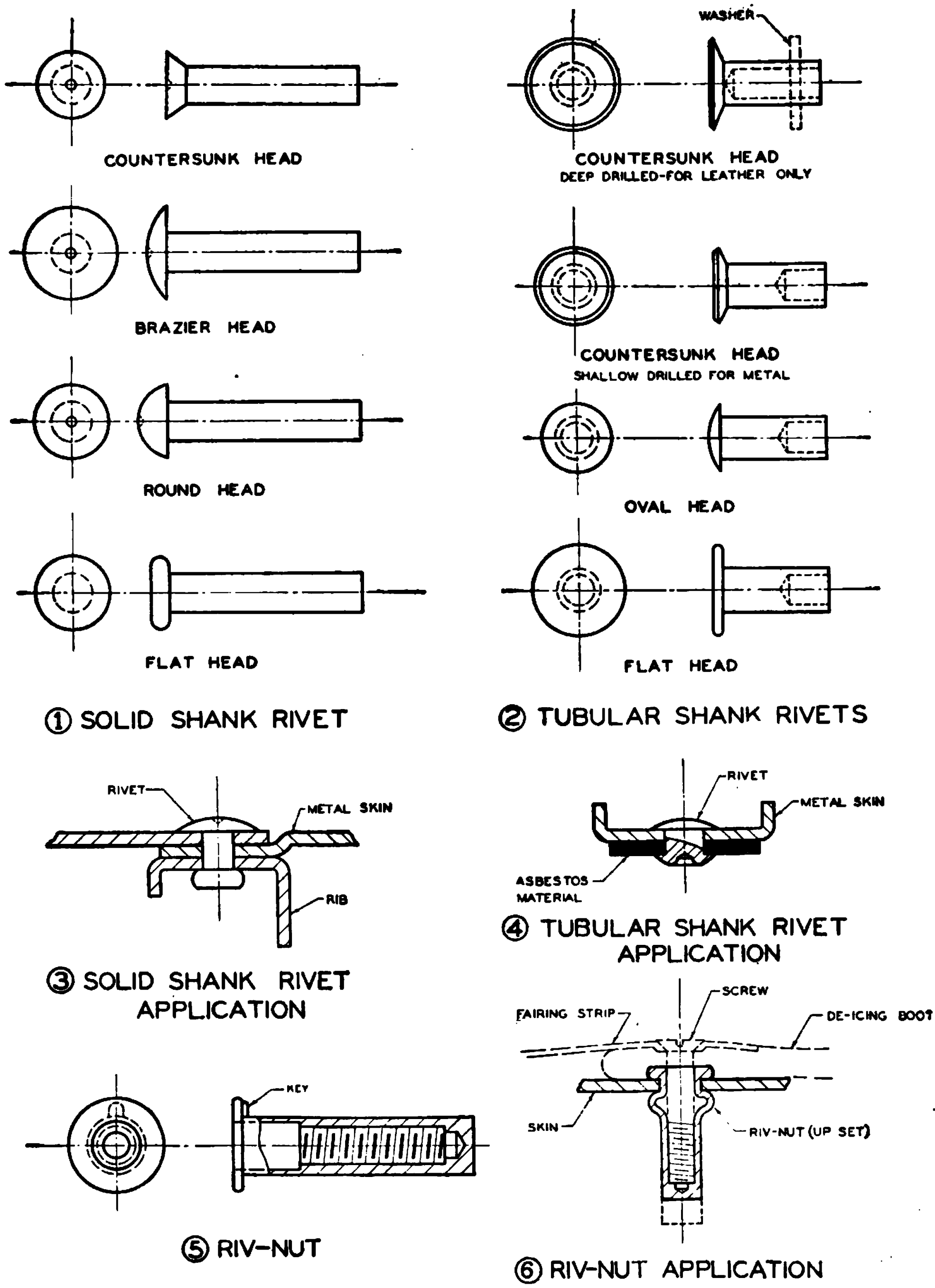


FIGURE 7.—Rivets.

cannot be properly accomplished if too little or too much of the shank projects; consequently, it is necessary to use a rivet of proper length. Hole sizes for rivets are given in table VII. Rivets in general use are

classified as solid shank, tubular shank, and a special type called the "Riv-Nut." Rivets are available in a variety of metals, the particular metal depending on the use for which the nut is intended.

a. Solid shank rivets (fig. 7 ①) are commonly used for sheet metal fastenings. Most of the rivets used on aircraft are of this type and are designated according to the various head designs: countersunk head, brazier head, round head, and flat head.

(1) The countersunk head rivet is adaptable for use on external surfaces of the aircraft.

(2) The round head rivet is used inside the aircraft where projecting heads are not objectionable.

(3) The flat head rivet is used in fuel tank construction.

(4) The brazier head rivet is also used on external surfaces of aircraft, and for patching. An application of this type of rivet is shown in figure 7 ③.

TABLE VII.—*Drill sizes for rivets*

Rivet size (inches)	Drill size	
	No.	Diameter in inches
1/16	50	0.070
3/32	36	.106
1/8	29	.136
5/32	19	.166
3/16	8	.199
1/4	------	17/64
5/16	------	21/64
3/8	------	25/64

b. The various types of tubular shank rivets are shown in figure 7 ②. For use with metal, the rivets are shallow drilled; the countersunk head type is available deep drilled for use with leather. An application of a tubular shank rivet is shown in figure 7 ④.

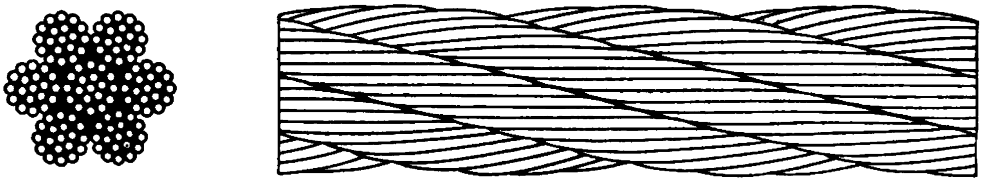
c. The Riv-Nut (fig, 7 ⑤) is designed for use on surfaces accessible from only one side. Upsetting is accomplished by use of a special tool which is screwed into the threaded part of the Riv-Nut. The tool applies a compression force to the Riv-Nut, causing it to bulge directly under the head as shown in figure 7 ⑥. A key on the under side of the head fits into a slot cut in the metal and thus prevents the Riv-Nut from turning. The Riv-Nut is used for attachment of de-icer boots; it may also be used in place of ordinary rivets for patching in places accessible from only one side.

33. Cables.—Steel cable is used in aircraft chiefly to operate flight controls and various release control mechanisms. The degree of flexi-

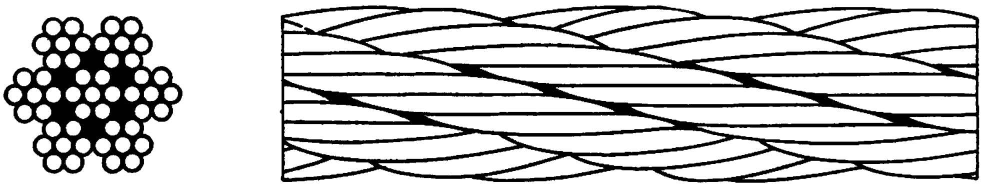
bility of control cable is determined largely by the number of strands and the number of individual wires composing the strands. A number of strands are laid helically around a single central strand to form the cable. The individual strands are similarly constructed.

a. (1) Extra flexible 7 by 19 aircraft cable (fig. 8 ①) is used for flight controls; its flexibility renders it highly resistant to bending fatigue. The cable is constructed of 7 strands, each having 19 wires.

(2) Flexible 7 by 7 aircraft cable (fig. 8 ②) is less flexible than the 7 by 19 cable, but is better able to withstand abrasion. It is used for



① EXTRA FLEXIBLE CABLE-7 X 19



② FLEXIBLE CABLE-7 X 7

FIGURE 8.—Aircraft cable.

release and auxiliary controls, and where it would not be subjected to heavy loads.

b. The five-tuck splice is used extensively for aircraft control cable terminals. A wrapped terminal is not used where the cable is subject to vibration, nor is it used in air controls. A swaged terminal may be used interchangeably with spliced or wrapped type terminals. Methods of splicing and wrapping cable terminals are explained in section VII.

34. Cable fittings.—Accessories are employed for use with cables for such purposes as adjustment, protection, or attachment. These accessories are made of steel with the exception of the turnbuckle barrel.

a. The turnbuckle assembly (fig. 9 ①) is a device which provides a means of adjustment of tension in aircraft cable. The assembly consists of a naval brass barrel (fig. 9 ②) fitted with two ends, one with right-hand threads and the other with left-hand threads. The three types of turnbuckle ends are known as fork (fig. 9 ③), pin eye (fig. 9, ④), and cable eye (fig. 9 ⑤). Applications of these ends are shown

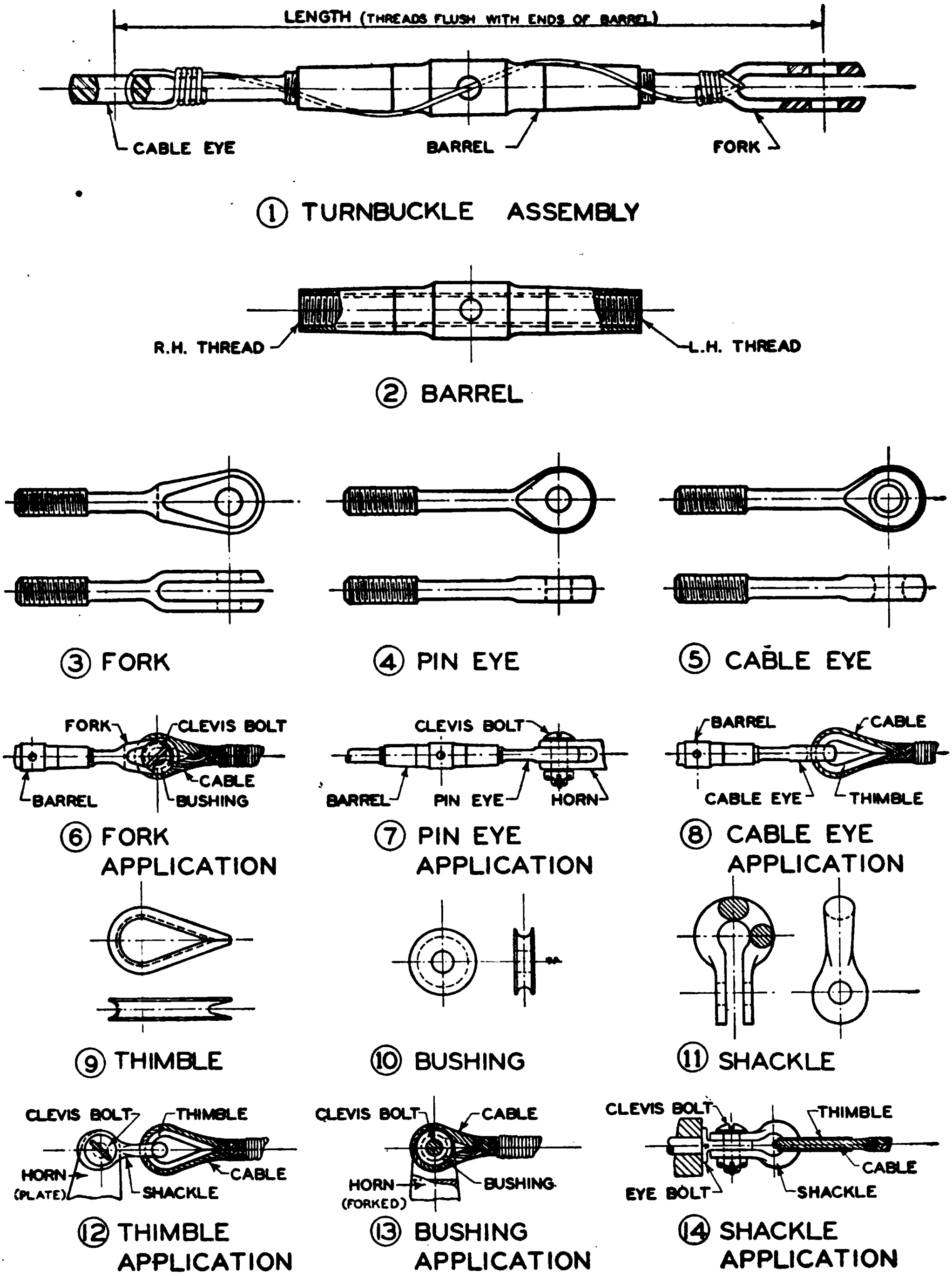


FIGURE 9.—Cable fittings.

respectively in fig. 9 ⑥, ⑦, and ⑧. The combination of ends determines the designation of the turnbuckle assembly. Four combinations of ends are used to form assemblies, known as cable eye and fork, cable eye and pin eye, cable eye, and fork. Adjustment of the assembly is accomplished by turning the barrel while the ends are held fixed; permanence of adjustment is insured by application of safety wire. The various parts of the assembly are specified as short or long. Strengths of units range from 550 to 17,500 pounds. When assembled, each turnbuckle end should have not more than three threads exposed.

b. The thimble (fig. 9 ⑨) is used to provide a means of protection against wear for the terminal eye of a cable; the thimble also serves as a form to shape the terminal eye properly. As shown in fig. 9 ⑧, ⑫, and ⑭, a cable terminal eye equipped with a thimble is used in conjunction with turnbuckle cable eye end or cable shackle. The use of the thimble on aircraft controls is limited to cable of 3/32 inch or smaller.

c. The bushing (fig. 9 ⑩) serves the same purpose as the thimble. It is commonly employed in conjunction with a turnbuckle fork end or form of clevis, as shown in fig. 9 ⑥ and ⑬.

d. The shackle (fig. 9 ⑪) is a clevis generally employed to connect cable to a plate fitting (fig. 9 ⑫), or eye bolt (fig. 9 ⑭). The shackle is attached to the terminal eye of the cable by insertion in the thimble before the cable is spliced or wrapped. Strengths of shackles range from 800 to 17,500 pounds.

35. Pulleys and fairleads.—These are accessories employed to insure efficient operation of control cable.

a. The control pulley (fig. 10 ①) is commonly used to effect a change in direction of control cable. Control pulleys are designed for allowable loads ranging from 200 to 10,000 pounds. On frequently used aircraft controls, pulleys of 1.25 or 2 inches in diameter should not be used to bend the cable more than 30° from a straight line.

(1) The pulley sheave is constructed of a fabric or equivalent reinforcing material processed to a hardness suitable for use with cable, and marked with the part number in permanent manner on one face.

(2) The pulley is furnished with the bearing (antifriction) lubricated with a grease intended to last for the life of the pulley under normal service conditions; the age-hardening characteristics of the lubricant should be such as to permit rotation of the inner race of the bearing with the fingers one year after delivery.

(3) The pulley is used with a stationary guard designed to prevent jamming.

b. The adjustable corner pulley (fig. 10 ②) is used with control cable in aircraft installations of carbon dioxide (CO_2) fixed fire extinguishing systems. The device is equipped with fittings to re-

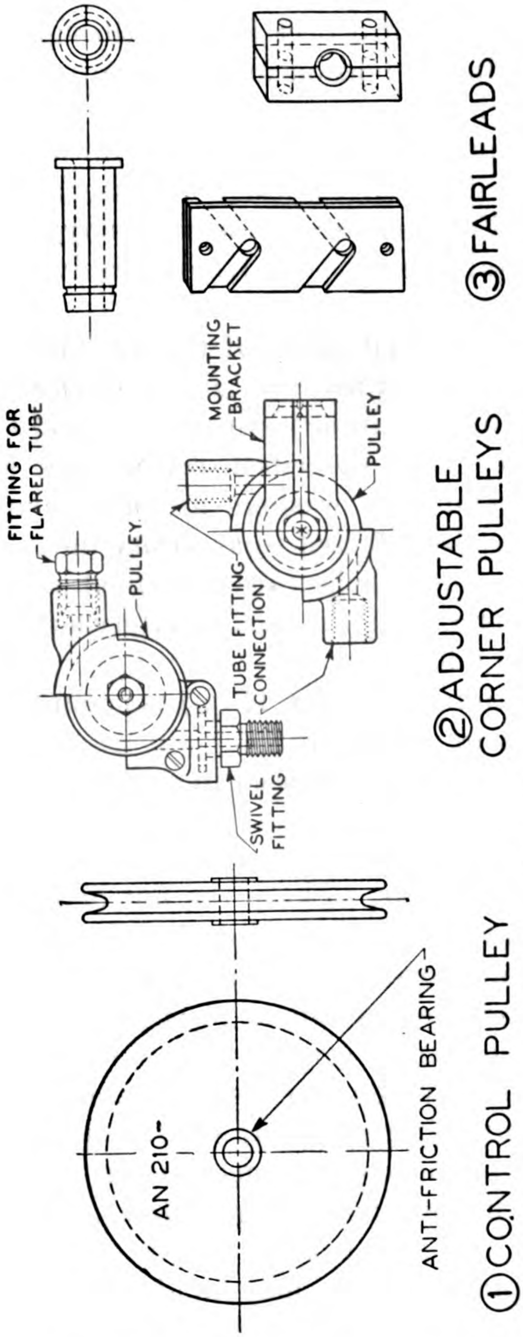


FIGURE 10.—Pulleys and fairleads.

ceive tubing (¼ inch outside diameter) through which the control cable passes. The fittings are movable to permit cable deflection up to 180°. One type is constructed with a swivel fitting for attachment to the gas cylinder bracket, the companion fitting receiving the con-

trol tubing; another type is equipped with two tube fittings and bracket for secure mounting.

c. Fairleads (fig. 10 ③) are used to prevent a cable from chafing or slapping against parts of the aircraft during flight or taxiing. A fairlead may be used to deflect a cable through an angle of not more than 2° if the initial tension in the cable is less than 50 pounds, and through an angle of not more than 1° if the initial tension is between 50 and 150 pounds; however, if the initial tension is greater than 150 pounds, a fairlead should not cause any angular change in cable direction. Fairleads are made of nonhygroscopic (not readily absorbing or retaining moisture), nonabrasive material, and are split to facilitate installation and removal.

36. Safety devices.—All parts of the aircraft intended for disassembly or adjustment require the use of devices to prevent accidental loosening or change in adjustment. In addition to lock nuts, check nuts, etc., previously described, cotter pins, safety wire, lock rings, safety pins, and lock washers are also commonly used for this purpose and may be referred to as safety devices (fig. 11). The methods of applying these devices are explained in section VII.

a. The cotter pin (fig. 11 ①) is used to safety a flat head pin (clevis pin) or a castellated nut.

b. The safety retaining pin (fig. 11 ②) is commonly used to safety the cover plate screw of a magneto.

c. The lock ring (fig. 11 ③) is used in conjunction with a threaded plug to lock it in place.

d. Lock washers (fig. 11 ④) are used in conjunction with plain nuts and various machine screws, to keep the nut or screw under tension and prevent accidental loosening. Lock washers are not considered as reliable as other approved safety devices and are generally limited in application to machine screws and sheet metal screws.

e. Copper wire, soft steel (galvanized) wire, and brass wire are commonly used for safetying purposes on aircraft.

37. Aircraft plumbing.—*a.* (1) Aircraft plumbing includes the hose, tubing, fittings, and connections used in fuel and oil systems, hydraulic systems, fire extinguishing systems, oxygen systems, and instrument installations.

(2) An aircraft plumbing line may be identified by its distinguishing colored band, painted at intervals along the tube length. Identification colors are given in table VIII.

b. Flared tube connections (solderless) are used extensively in airplane plumbing systems. The fittings commonly used for this type connection are shown in figures 12, 13, and 14, and include the 811 type, the swivel type, and the universal type.

TABLE VIII.—*Identification colors for aircraft plumbing lines*

Line	Color of band
Fuel	Red.
Oil	Yellow.
Water	White.
Prestone	White band on each side of a black band.
Fire extinguisher	Brown.
Flotation equipment	Light blue.
Oxygen	Light green.
Air speed indicator (pressure)	Black.
Air speed indicator (static)	Alternate black and light green.
Manifold pressure	Alternate white and light blue.
Vacuum	Alternate white and light green.
Hydraulic	Light blue on each side of yellow.
Air	Alternate light blue and light green.
Steam	Alternate light blue and black.
Purging	Alternate light blue and yellow.
Exhaust analyzer	Alternate light blue and brown.
Anti-icing fluid	Alternate white and red.
Vent	Alternate red and black.

(1) The 811 type consists of a sleeve (fig. 12 ①), a coupling nut (fig. 12 ②), and any one of the flared tube fittings shown in figure 12 ③ to ⑧, inclusive. The sleeve is made of a copper-silicon alloy or nickel steel and provides support for the tubing at the point of attachment. Coupling nuts and fittings are brass, aluminum alloy, or nickel steel. Nickel steel nuts, sleeves, and fittings are used on steel tubing only. Copper-silicon alloy sleeves are used with brass or aluminum alloy fittings and with steel fittings ½ inch and greater. The nipple (fig. 12 ③) permits a flared tube connection to a unit tapped with a pipe thread. The connector (fig. 12 ④) has an internal pipe thread for attachment to pipe fittings. The union (fig. 12 ⑤) is used for a straight connection between sections of tubing. The elbow (fig. 12 ⑥ and ⑦) provides an angular connection and obviates bending of the tube. The tee shown in figure 12 ⑧ is used for a three-way connection. A flared tube connection with this type of fitting is shown in figure 12 ⑨. The seal is established between the tube and the fitting at the flare, and not in the threads. A properly installed connection of this type will withstand the high operating pressure of the aircraft hydraulic system.

(2) The universal type fitting, figure 13, can be positioned as desired with respect to the line attached. In assembling, the nut (fig. 13 ⑤) is run on the fitting (fig. 13 ②, ③, or ④) far enough to clear the gasket groove. The gasket (fig. 13 ⑥) is placed in the gasket groove, and the fitting is screwed into the boss until the gasket touches the boss. The fitting is then unscrewed (not more than 360°) to locate it in the approximate position desired. The lock nut is tightened lightly and

the line assembled to the fitting. The fitting is finally secured in place by tightening the lock nut against the boss. The union (fig. 13 ①) requires no positioning and is assembled by placing the gasket in the groove and tightening the fitting against the boss. Universal fittings

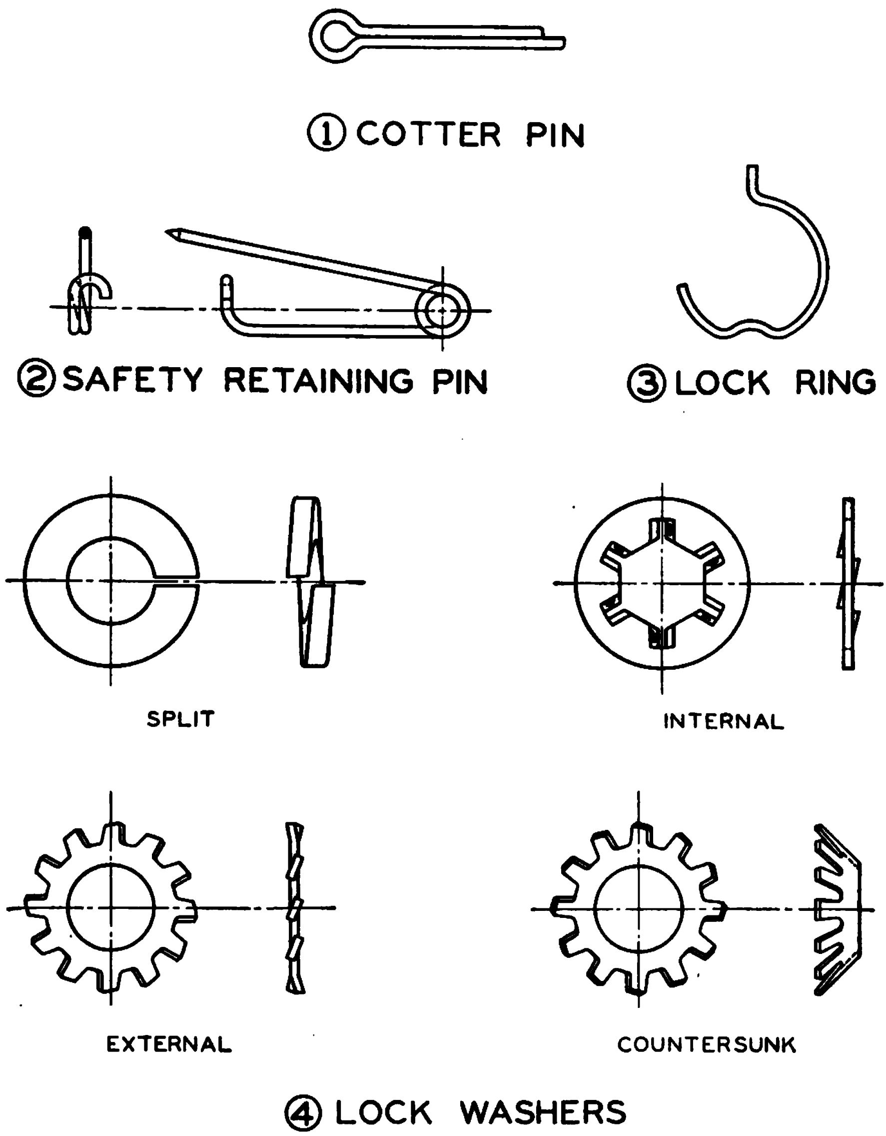


FIGURE 11.—Safety devices.

are made of aluminum alloy or steel. The nut is made of steel or aluminum alloy and the gasket is of oil-resistant synthetic compound.

(3) The swivel type fitting, figure 14, can also be positioned. Swivel type and universal type complete assembles may be used interchangeably. Swivel type fittings are made of aluminum alloy or steel. The gasket is of copper or aluminum.

c. The cone union connection consists of a cone union (fig. 15 ①), a coupling nut (fig. 15 ②), and any one of the fittings shown in figure 15 ③ to ⑦, inclusive. The cone union is silver soldered to the tubing, and the connection completed by drawing the cone tightly against the fitting with the use of the coupling nut (fig. 15 ②). The seal is established between the cone and the fitting. The tee and the 45° and 90°

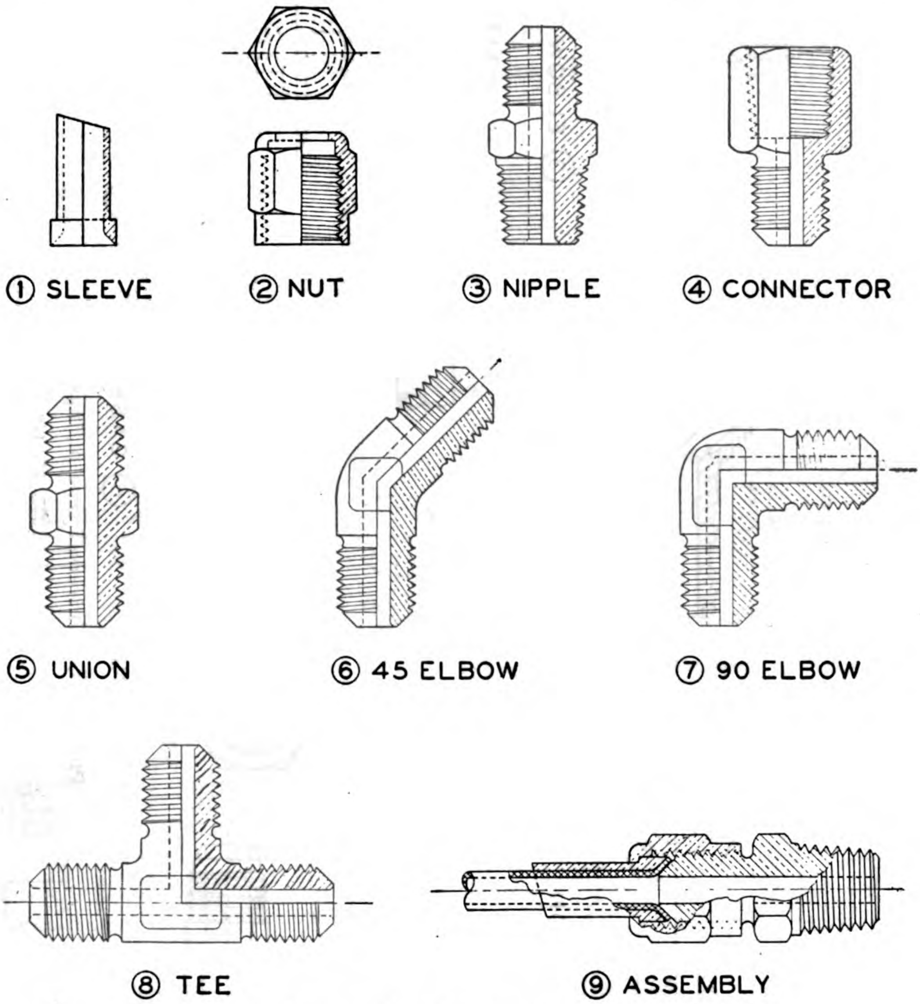


FIGURE 12.—811 type fittings.

elbows are made of bronze; the other units are brass. This type of connection is generally used in instrument lines.

d. Two types of drain cocks are illustrated in figure 16. The type shown in figure 16 ① is used only for oil or water drainage. The screw type (fig. 16 ②) is used for fuel drainage. Drainage is accomplished in some installations by use of threaded plugs. Drain cocks and plugs are provided with holes for application of safety wire.

e. The pipe flange (fig. 16 ③) is supplied with pipe or straight threads and affords a means of connecting tubing or a pipe fitting to a tank. The flange is riveted or welded to the tank.

f. Tube clips (fig. 17 ① and ②) made of aluminum alloy are used to support tubing or conduit and prevent excessive vibration of these

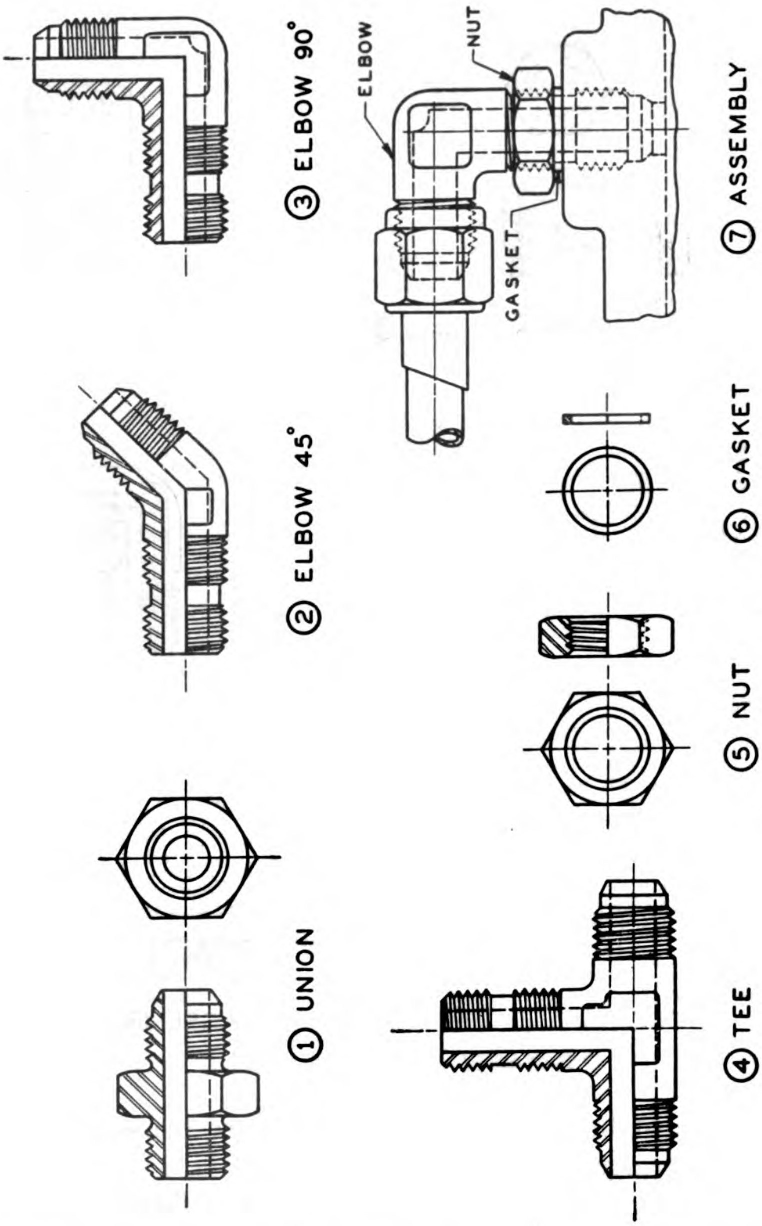


FIGURE 13.—Universal type fittings.

lines during flight. A rubber bushing is installed between the pipe and the clip to protect the pipe. Typical applications of the clips are shown in fig. 17 ③.

g. (1) Wherever there is relative motion between two points connected by piping, a flexible hose connection is used at each point.

Flexible synthetic hose connections have application in fuel, oil, and cooling systems. Tube ends on which flexible connections are to be placed are beaded to prevent the hose from slipping.

(2) Hose connections should have a minimum length of one-quarter inch exposed to liquid flow in order to provide flexibility, and a maximum exposed length of one hose diameter if the system is under suction.

h. Hose nipples are available with pipe thread or straight thread as shown in figure 18 ①. The straight thread nipple is used for connec-

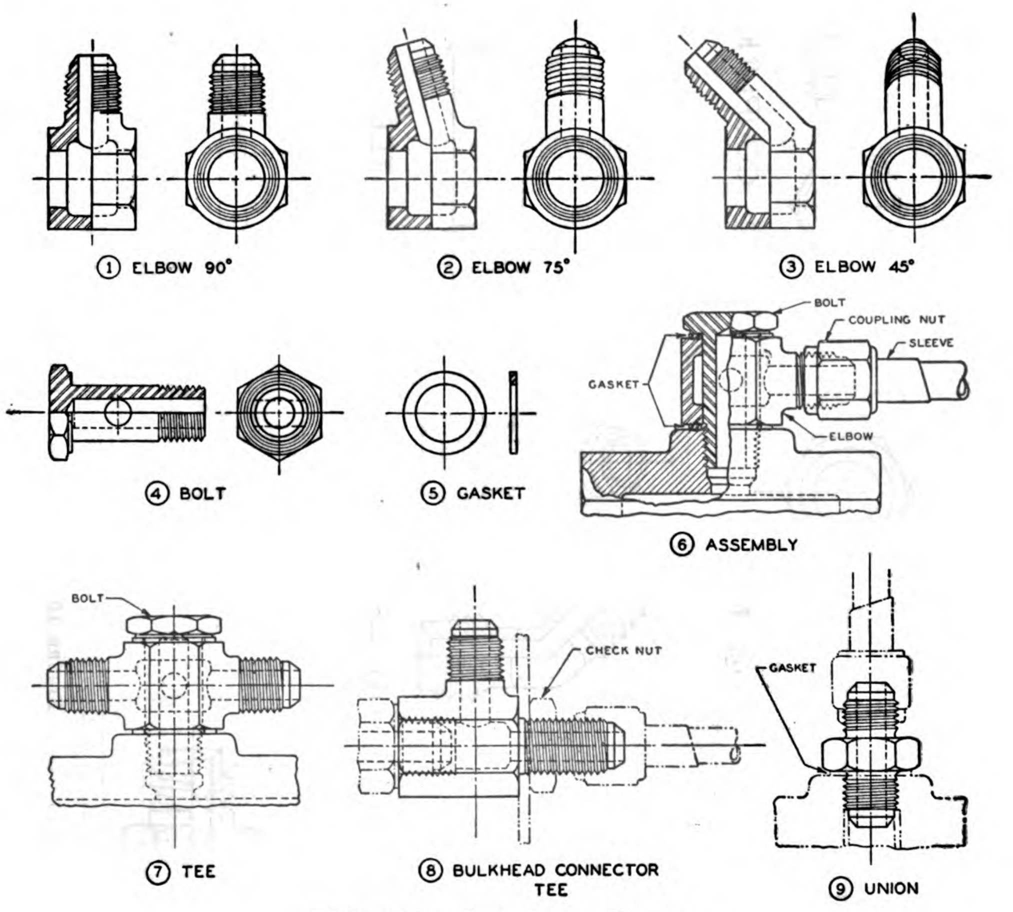


FIGURE 14.—Swivel type fittings.

tion to a flared tube fitting. A shoulder is provided on the nipple end to prevent the hose from working off. The round-shouldered nipple is intended for use with either one or two hose clamps, depending upon the length of end. The high bead nipple is replacing the round-shouldered type and one clamp is being used instead of two.

i. (1) Two types of hose clamps commonly used on aircraft are illustrated in figure 18 ②. After adjustment, not less than three threads should remain exposed on the bolt of the wing nut type clamp. If

fewer than three threads remain exposed, the clamp should be removed and the bolt inserted in another hole which will permit proper tightening. Figure 18 ③ illustrates a hose connection with thumbscrew type clamp.

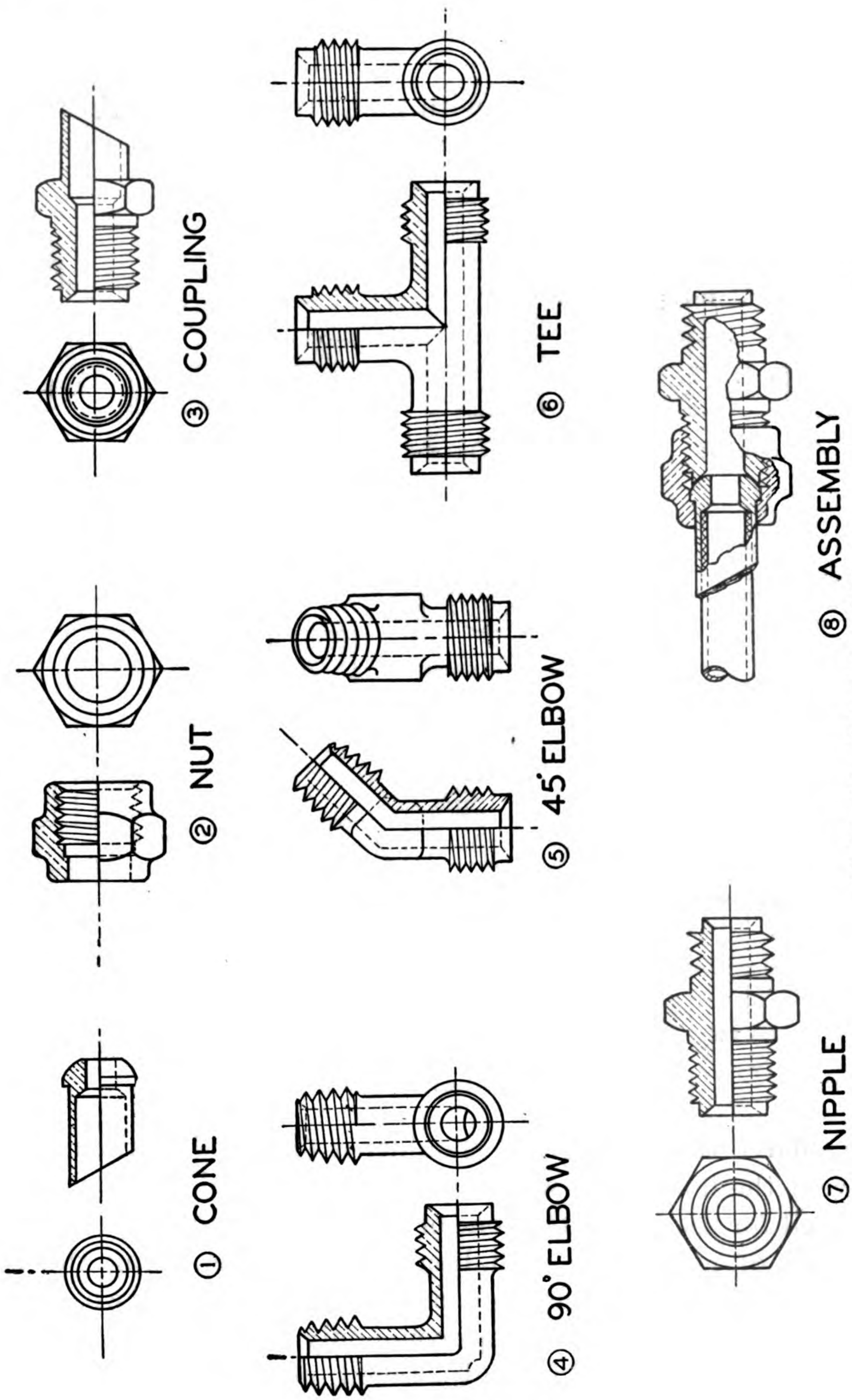


FIGURE 15.—Cone union fittings.

(2) Hose clamps should provide effective bearing on the complete circumference of the hose under the clamp. The adjusting screw should be of the thumbscrew type and should require no special tools

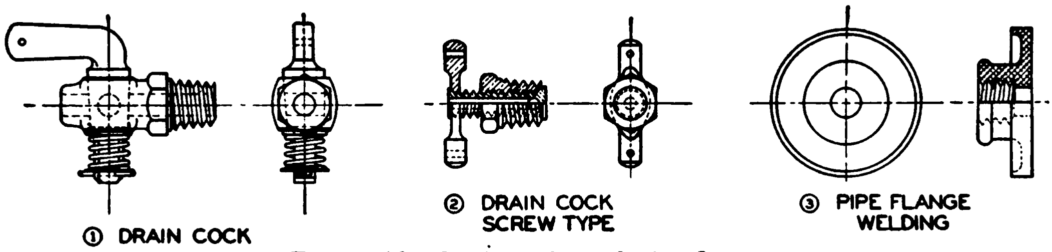


FIGURE 16.—Drain cocks and pipe flange.

for tightening the clamp. The thumb grip should be provided with a hole for safetying with wire.

j. The hose assembly (fig. 18 ④) is a complete unit with the connectors attached. It is used for connections to units requiring free

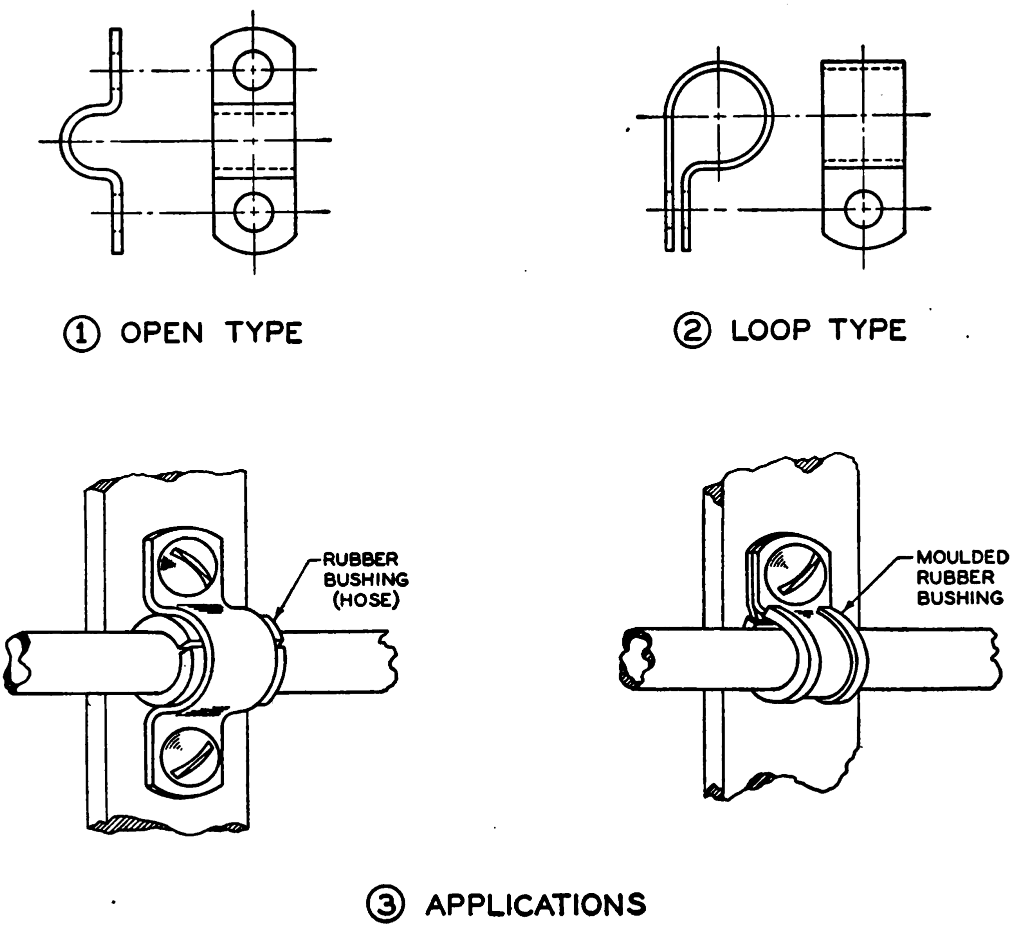


FIGURE 17.—Tube clips.

movement, such as actuating cylinders in hydraulic systems. The maximum operating pressure of hose should be one-fifth the design burst pressure.

38. Rods and fittings.—*a.* Rods used in aircraft may be classified generally either as tie rods or control rods.

(1) Tie rods (fig. 19 ①) are made of high strength steel and are used for bracing purposes. The streamlined tie rod is used for external

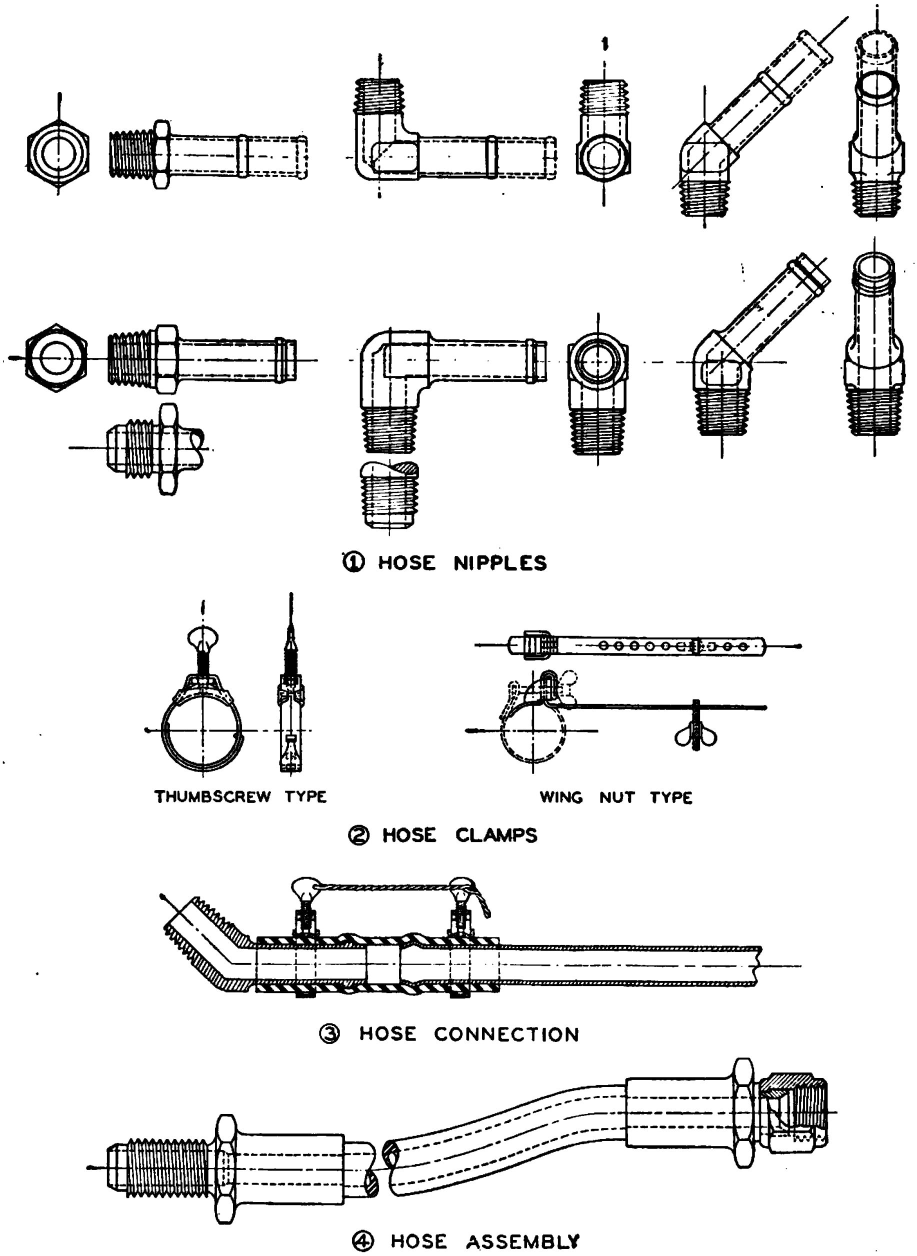


FIGURE 18.—Hose connections and fittings.

applications, whereas the round and square types are used internally. The ends of a tie rod are oppositely threaded, and adjustment of tension is accomplished by turning the rod. The circular tie rod is provided with "flats" near each end to accommodate a wrench.

(2) Control rods are used extensively in the various engine control arrangements (throttle, mixture, carburetor air heat, cowling, shutter, etc.). Such rods are usually tubular steel.

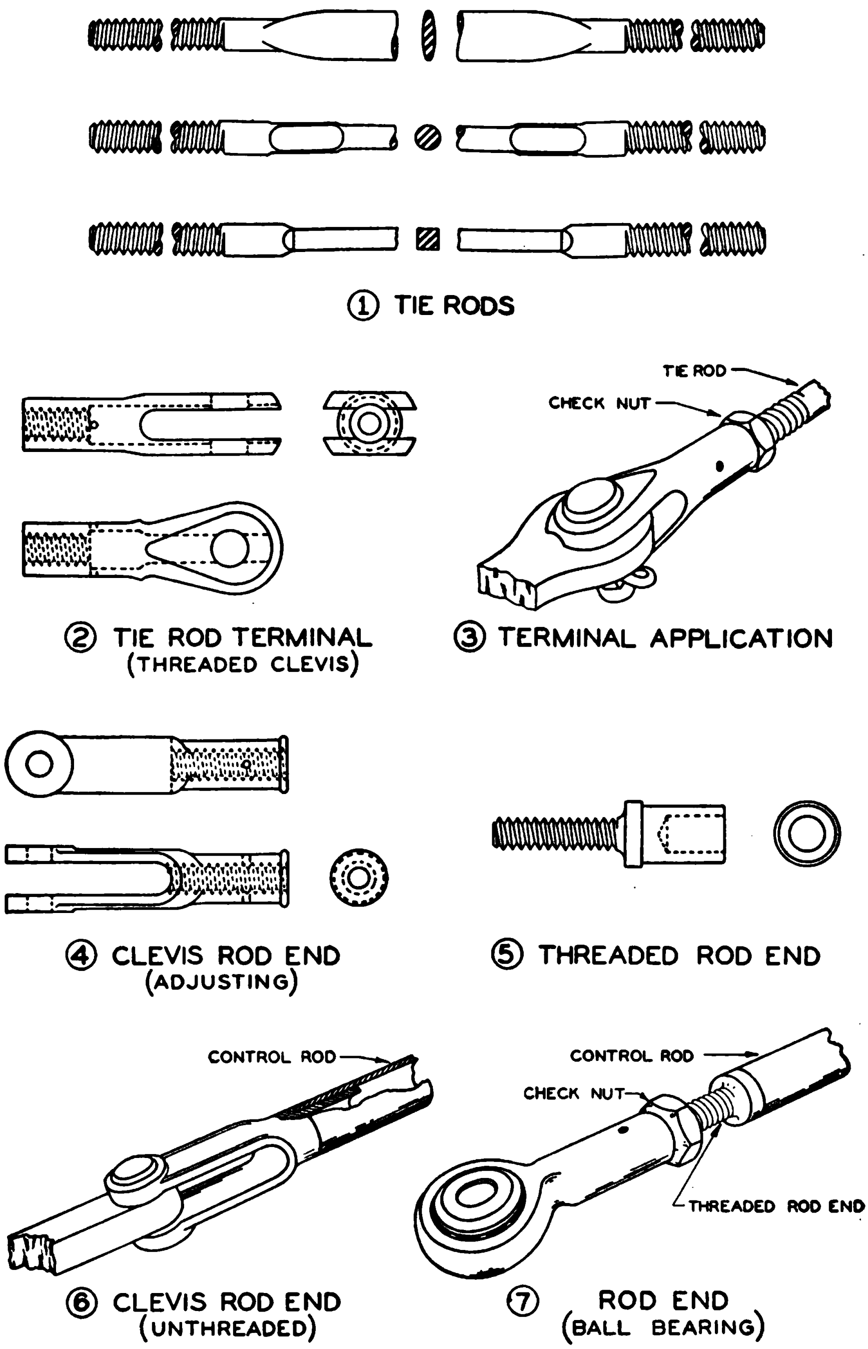


FIGURE 19.—Rods and rod ends.

b. (1) The terminal or end used in conjunction with a tie rod is a threaded clevis shown in figure 19 ②. Such terminals are available with right- or left-hand threads to correspond with the threads on the

tie rod. A small inspection hole in the terminal, just beyond the thread limit, is used to determine whether the rod is threaded into the terminal for a safe distance; if the rod end does not extend beyond this hole, a longer rod should be used. The application of the terminal is shown in figure 19 ③.

(2) Various rod ends are used in conjunction with control rods for attachment to a crank arm, lever, etc.

(*a*) The threaded clevis end (fig. 19 ④) is adjustable and is also provided with an inspection hole. The type of end is adapted to a tubular control rod by use of a threaded rod end (fig. 19 ⑤).

(*b*) The unthreaded clevis end (fig. 19 ⑥) is used with tubular control rods and is attached directly to the rod.

(*c*) The ball bearing rod end (fig. 19 ⑦) has extensive application, and is particularly adaptable where the control rod tends to twist during its movement. This type of rod end is also adapted to the control rod by use of a threaded rod end, and is provided with an inspection hole.

(*d*) The universal joint (fig. 20) is used to transmit rotational movement between control rods or between a control rod and a mechanism, where the axes of the rotating members are at an angle to each other. The universal joint may be used in fuel cock, engine, armament and flap controls, and landing gear retracting mechanisms, etc. The joint is available in light and heavy duty types. The working parts of the heavy duty type are enclosed within a flexible cover to exclude dust and dirt and retain lubricant.

39. Pins.—*a*. The flat head pin (fig. 21 ①), commonly called clevis pin, is made of steel and is used in conjunction with a tie rod terminal (fig. 19 ③). It may also be used in secondary controls which are not subjected to continuous operation and where the chances of becoming loose are negligible. The pin should be safetied with a cotter pin. The pin should be installed with the head up so that in the event the cotter pin should fail, or work out, the pin will tend to remain in place.

b. Taper pins are made of steel and are used in connections which are seldom broken and where the absence of play is essential.

(1) The plain taper pin and its applications with a universal joint is shown in figure 21 ② and ③. The plain taper pin is drilled, and safetied with wire.

(2) The threaded taper pin and its application with sprocket on a trim tab control is shown in figure 21 ④ and ⑤. The threaded taper pin is used with a taper pin washer and shear nut (safetied with cotter pin) or self-lock nut.

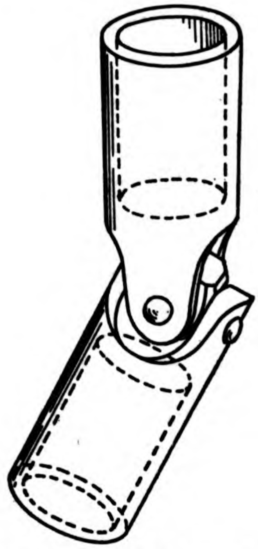


FIGURE 20.—Universal joint.

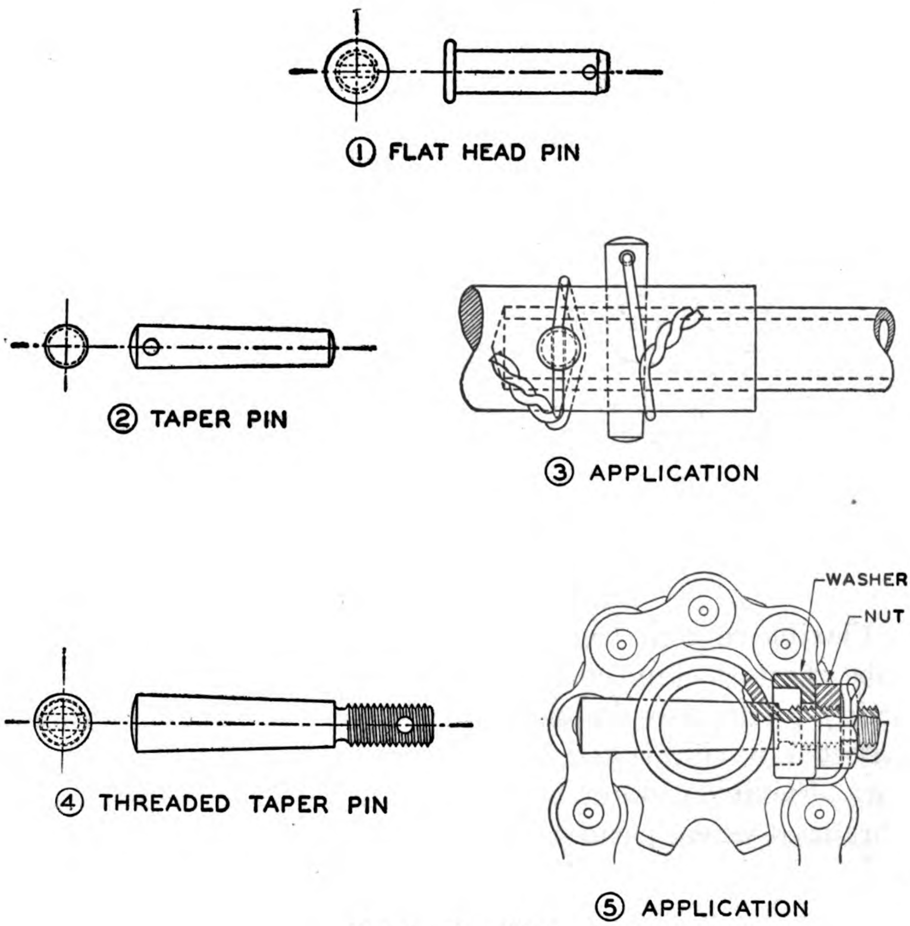


FIGURE 21.—Pins.

40. Wiring equipment.—*a.* (1) In aircraft, conduit serves to protect electrical conductors and to prevent radio interference by acting as an electrostatic shield.

(*a*) Rigid conduit (fig. 22 ①) is made of aluminum alloy and is used for installations of a relatively permanent nature. Rigid conduit is securely attached to aircraft structural members and is used extensively to encase wiring in the fuselage and wing sections.

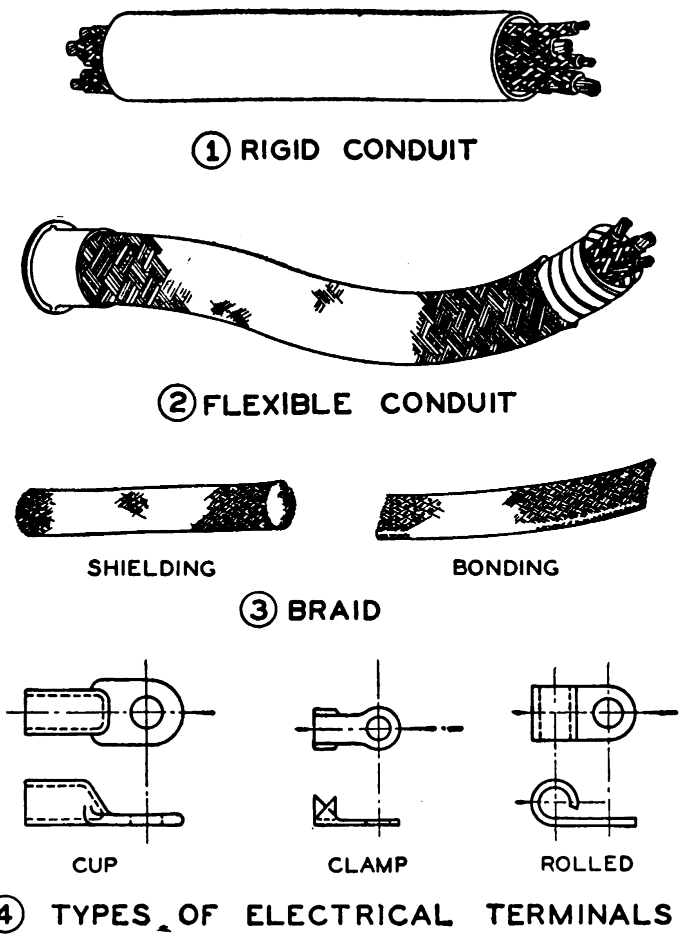


FIGURE 22.—Wiring equipment.

(*b*) Flexible conduit (fig. 22 ②) consists usually of a flexible aluminum tube of interlocking construction, covered with wire braid (shielding braid) to improve its shielding properties. Flexible conduit is little affected by vibration, and consequently is used where vibration is a factor. Flexible conduit is also easily removed and installed and is therefore used where periodic disconnection is required.

(2) Installation of conduit involves the use of conduit fittings. Types of conduit fittings and manner of assembly are shown in figures 23 and 24.

b. Tinned copper braid (fig. 22③) is used for both shielding and bonding purposes, except where flexible aluminum conduit is used; in this case, aluminum braid is used. Braid which is used to interconnect electrically isolated metallic parts of the aircraft is known as bonding braid.

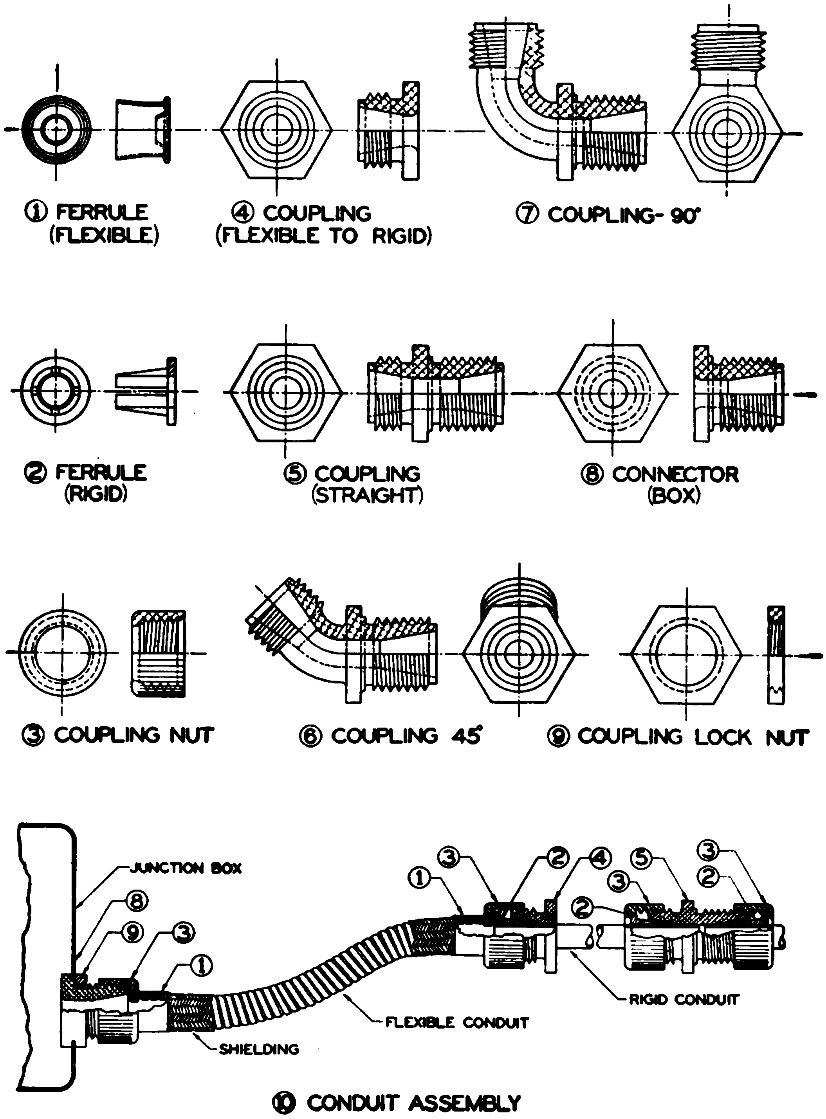


FIGURE 23.—Conduit fittings.

c. In figure 22 ④ are shown three types of terminals (copper soldering lugs) used on aircraft as a convenient means of connecting wiring to electrical equipment. The cup type is used on cables larger than No. 16 American wire gage, and is available in capacities ranging from 25 to 325 amperes. The clamp type is used for cables No. 16 and smaller. The rolled type is generally used on cables larger

than No. 16, and is available in capacities ranging from 15 to 125 amperes.

41. Miscellaneous equipment.—*a. Grommets.*—Celluloid grommets (fig. 25 ①) are employed to drain fabric-covered airfoils, such as wings, ailerons, and elevators. Grommets are located on the un-

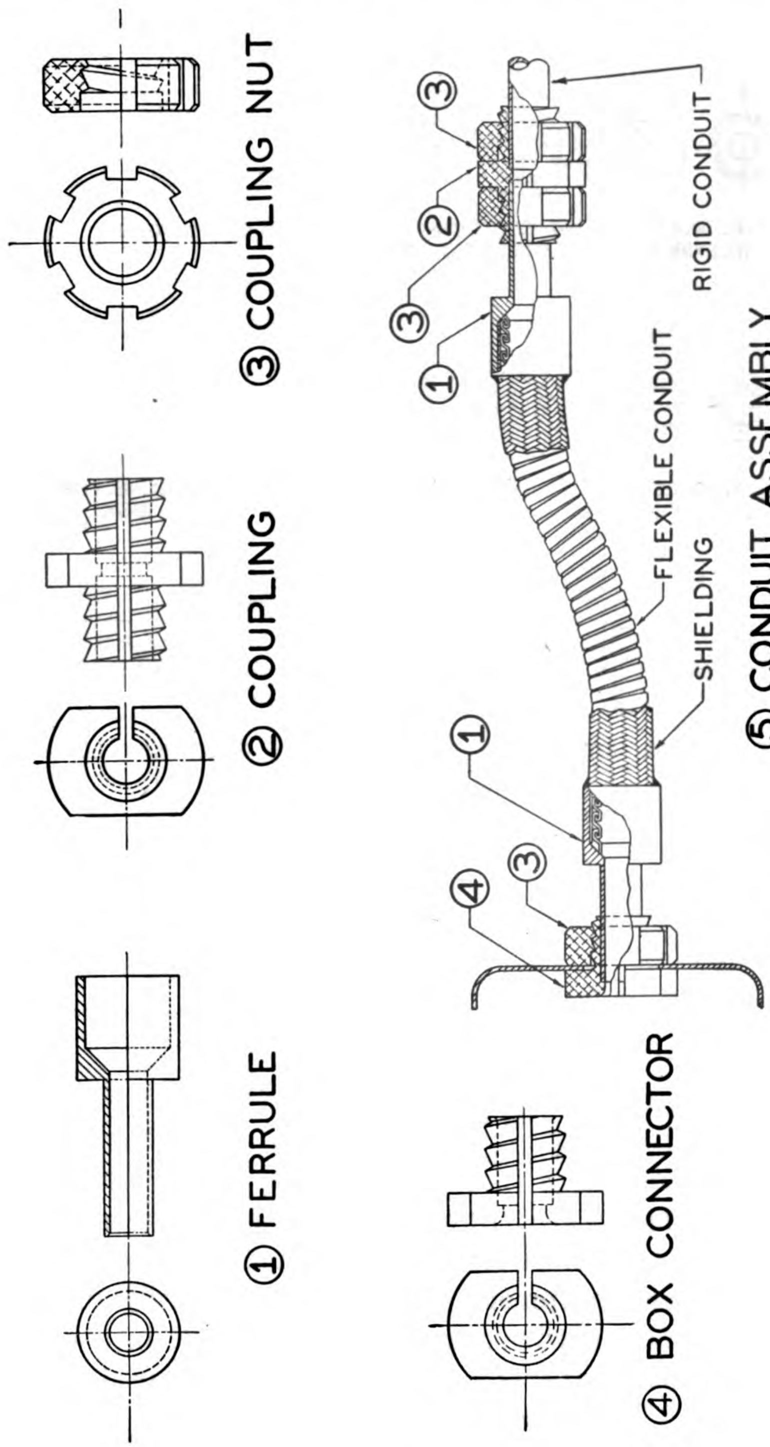


FIGURE 24.—Conduit fittings.

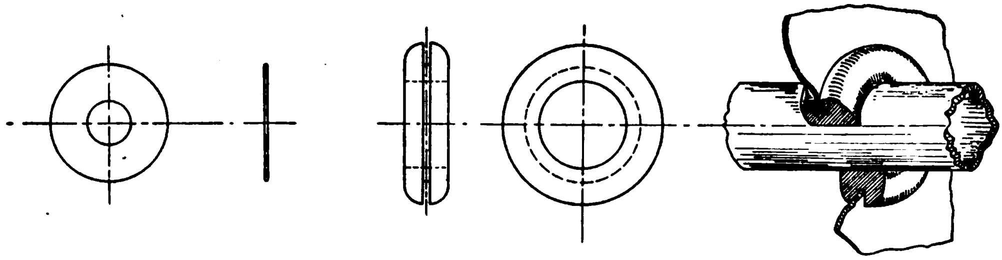


FIGURE 25.—Grommets.

derside of the trailing edge, close to the rib, and are doped directly to the main covering. Care should be exercised to insure that the hole in the grommet is unobstructed. If a brass grommet is used it is mounted on a fabric patch. The Neoprene grommet (fig. 25 ②) is used to line and protect the edges of holes in sheet metal through which tubing or conduit passes. The grommet prevents vibration and chafing.

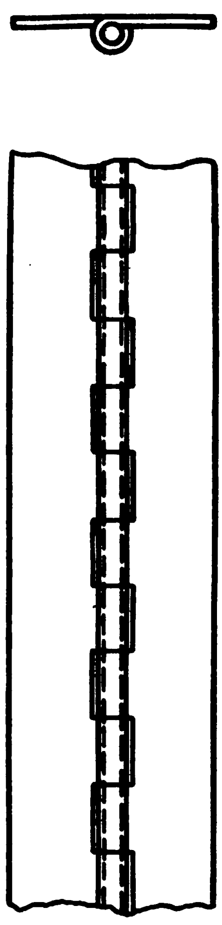


FIGURE 26.—Continuous hinge.

b. Continuous hinge.—The continuous hinge (fig. 26) is used in aircraft in such installations as inspection cover plates, compartment doors, wing flaps, trim tabs, bomb doors, etc. Continuous hinges are made of stainless steel or aluminum alloy, depending upon the installation. When a continuous hinge is used on a control surface, it is fabricated of stainless steel.

c. Pressure-grip lubricator fitting.—The lubricator fitting shown in figure 27 is used on various aircraft mechanisms where grease is required for lubrication, to provide a means of attachment for a grease gun. The fitting is available in the shapes illustrated, to permit access to various installations. The fitting operates on the principle of a check valve, permitting the grease to enter but preventing it from backing out.

d. Fasteners.—The flush type fastener (Dzus) shown in figure 28 is used to secure cowling, and inspection plates, panels, etc., situated

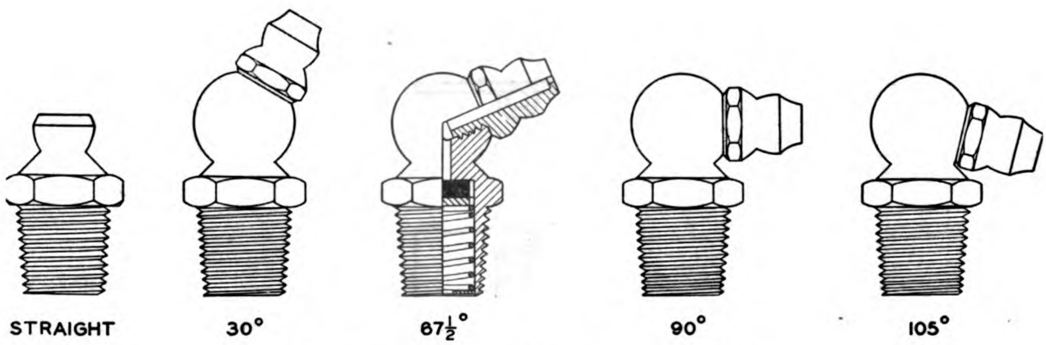


FIGURE 27.—Pressure lubricator fittings.

on the external surface of the aircraft where streamlining is desirable and frequent removal is required. The wing type is used in the interior of aircraft on such parts as junction box and control panel covers. The complete unit consists of a stud, grommet, and spring as shown in the assembly. A quarter turn of the stud serves to lock or loosen the fastener.

SECTION VII

PROCESSES RELATED TO HARDWARE

42. Application of safety devices.—Vibration in aircraft tends to loosen or alter the adjustment of various parts, such as nuts, turnbuckles, etc.; consequently, parts which are intended for disassembly

or adjustment are generally made secure or "safetied" by means of auxiliary devices or self-contained features. A part having a self-contained safety feature requires only the application of the part itself. The manner of application of the various auxiliary safety devices is discussed below.

a. Application of cotter pin.—(1) The Air Corps Standards Book specifies the size of cotter pin to be used with each size of unit which is drilled to receive a cotter pin. For example, a 1/4-inch (diameter) bolt is drilled to receive a cotter pin 1/2 inch in length and 1/16 inch

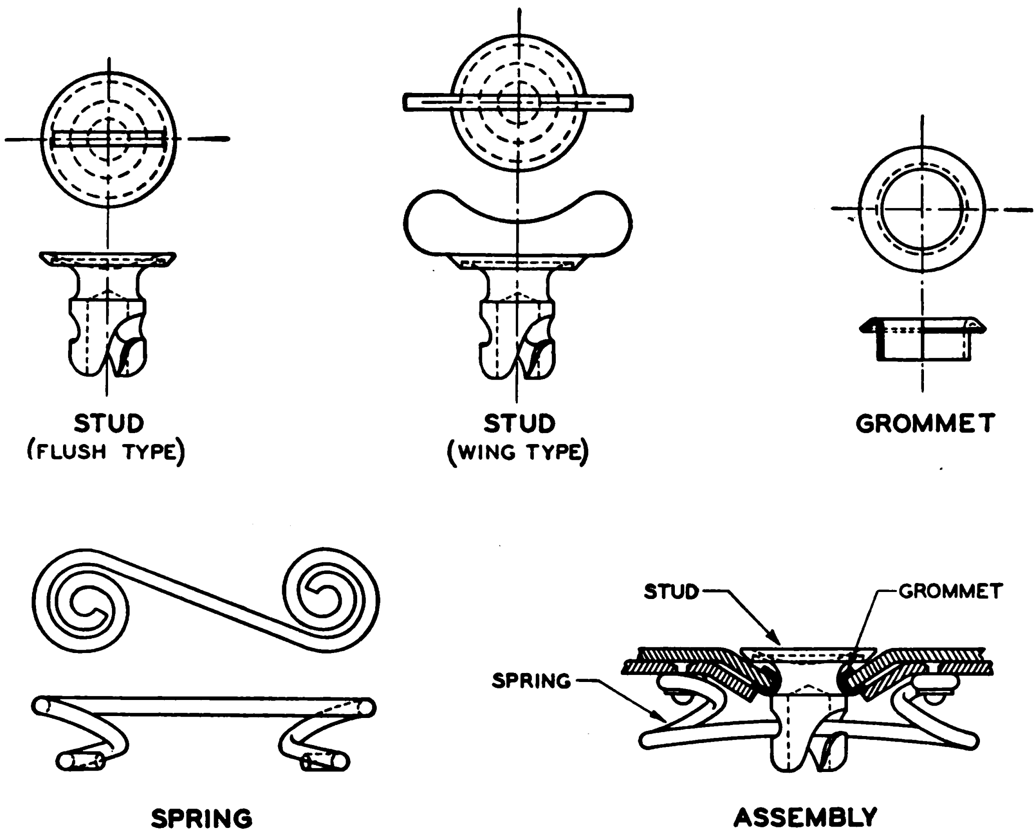


FIGURE 28.—Sheet metal fasteners.

in diameter; a 1/2-inch bolt is to be used with a cotter pin 3/4 inch in length and 3/32 inch in diameter. Steel wire 0.041 inch in diameter is used in an installation which requires a cotter pin smaller than 1/16 of an inch in diameter.

(2) (*a*) The application of a cotter pin with a castellated nut is shown in figure 29 ①. One pair of opposite castellations should be lined up with the hole in the bolt. The cotter pin is inserted (longer prong up) and tapped lightly into place to insure a snug fit at the eye. The prongs are spread and bent as shown, the top prong being bent first. During bending a slight pull should be

exerted with the pliers to keep the eye of the cotter pin in snug contact with the bolt. The prongs are brought flat against the top of the bolt and side of the nut by light tapping.

(*b*) The application of a cotter pin with a flat head pin is shown in figure 29 ②.

(*c*) If, during installation, there is a possibility of a cotter pin falling into an inaccessible part of the assembly or surrounding mechanism, a piece of thin wire should be fastened loosely to the eye of the cotter pin before insertion into the hole; after the pin is made secure the wire should be removed. If proper length of cotter pin is not available, a longer length may be used; in such case, the prongs are cut with pliers to permit the upper prong to reach to approximately half to two-thirds across the top of the bolt, and the lower prong close to the bottom of the nut. When it becomes necessary to cut a cotter pin, the palm of the hand should be cupped over the pin to catch the flying fragment, thus preventing possible injury to the person, or lodging the fragment in the mechanism.

(*d*) When removing a cotter pin, the prongs should be straightened with pliers and the pin removed by inserting the pointed end of a cotter pin extractor into the eye of the pin or grasping the eye with pliers, and drawing the pin carefully through the hole. A cotter pin should not be used a second time.

b. Application of lock nut.—This safety device is applied after the regular plain nut is tightened to the desired tension. The lock nut is tightened with the fingers against the plain nut (fig. 29 ③). It is then given approximately one-sixth of a turn with a wrench (a lock nut should never be tightened more than one-fourth of a turn). When a lock nut is removed, it must be loosened with a wrench and threaded off before the plain nut is loosened. A lock nut and plain nut should never be tightened or loosened at the same time.

c. Application of check nut.—An application of a check nut is illustrated in figure 29 ④. A plain nut is first tightened to the desired tension; the check nut is then threaded onto the bolt and turned tightly against the plain nut with a wrench. The plain nut should be held with another wrench to prevent it from turning while the check nut is being tightened. Applications of the check nut with rod ends are shown in figures 29 ② and 19 ⑦.

d. Application of lock washer.—An application of a split lock washer is illustrated in figure 29 ⑤. As the screw is drawn up tightly, the lock washer is flattened and exerts a pressure by spring action against the under side of the screw head. The threads of the screw are thus kept under tension and resist any tendency of the screw to loosen. When used against soft metal the lock washer tends to dig

in instead of flatten and thus loses its spring action and effectiveness; this may be avoided by use of a plain washer placed between the lock washer and the fitting or casting. In figure 29 ⑥ is shown the application of a lock washer in a battery terminal connection. A plain

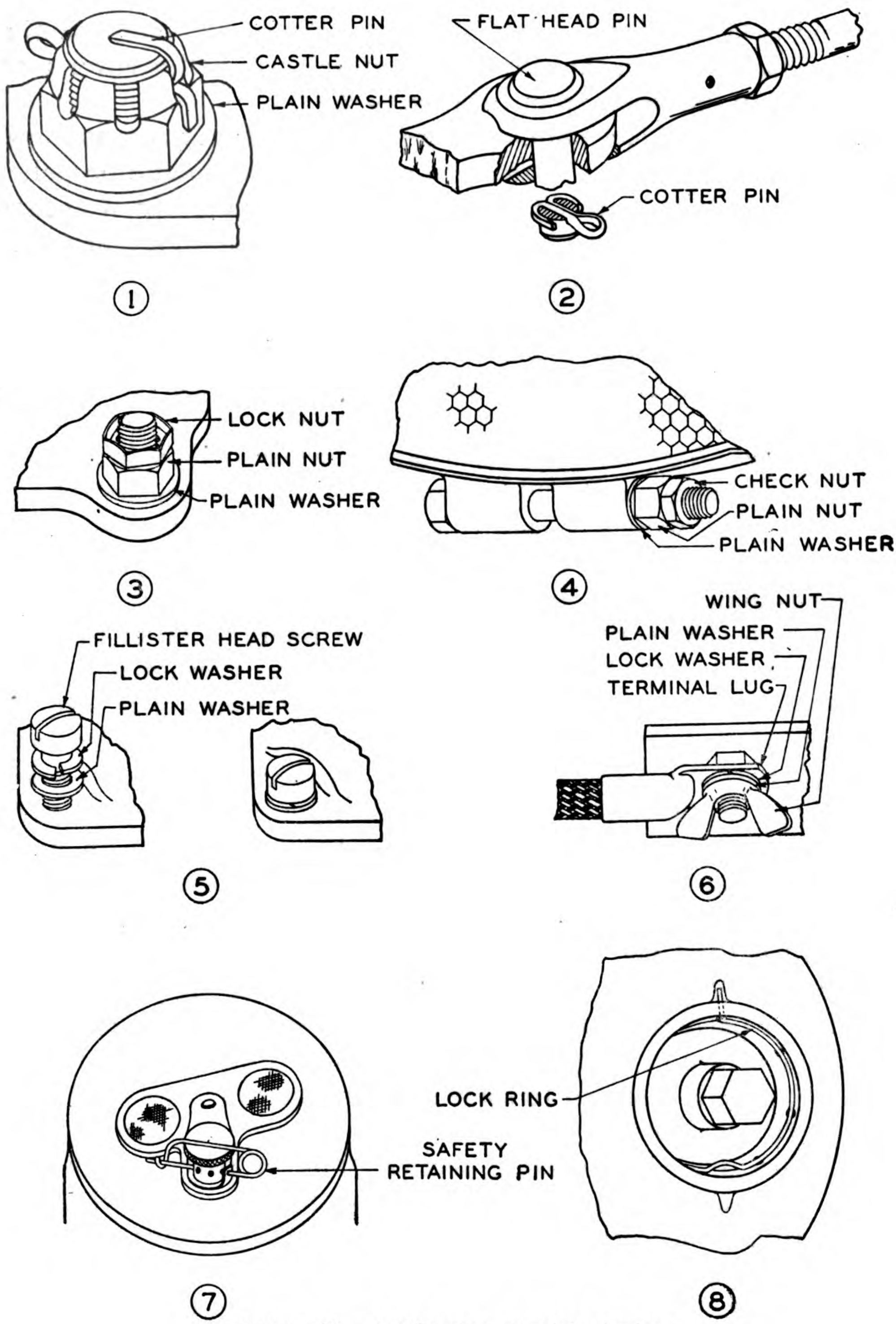


FIGURE 29.—Application of safety devices.

washer is placed between the wing nut and the lock washer for the reason that the projecting end of the lock washer would scrape the lead coating from the nut and hasten corrosion.

e. Application of safety retaining pin.—In figure 29 ⑦ the safety retaining pin is shown passing first through a lip on a magneto cover plate and then through the drilled head of the cover plate retaining screw. The safety pin thus insures the attachment of the cover plate by preventing the screw from turning.

f. Application of lock ring.—In figure 29 ⑧ the lock ring is shown as used in conjunction with the dome plug of a hydromatic propeller. Either oppositely located slot in the dome serves as a means of anchorage for the prong of the lock ring. To lock the plug, a hole in the plug must be lined up with either slot in the dome. The prong of the lock ring is placed through the hole in the plug and into the slot in the dome; the ring is then snapped into a grooved seat in the plug. A part of the ring is bent out from the grooved seat to facilitate removal of the lock ring.

g. Application of safety wire.—Parts such as drilled head bolts, fillister head screws, turnbuckles, thumbscrews, plugs, etc., are safetied with wire. The wire is generally applied by twisting, as shown in figure 30. The wire must be taut and twisted close to the parts. The twisting is done by hand with the exception of the final four or five twists, which should be accomplished with pliers in order to apply tension and secure the end of the wire properly. Careless use of the pliers may result in damage to the wire and its consequent failure. In all applications the wire should be arranged between the parts or between a part and anchorage, in such a manner so as to oppose any loosening of the part.

(1) A filler plug properly safetied with wire is shown in figure 30 ①. In this installation the wire is anchored to a separate safetying lip on the housing. This same method of safetying is applied to wing nuts, drilled head bolts, fillister head screws, etc., which are to be safetied individually. Ordinarily, anchorage lips are conveniently located near parts to be safetied individually with wire as in the case of the plug shown in figure 30 ⑤. When such provision is not made, the safety wire is fastened to some adjacent part of the assembly, as shown in figure 30 ② and figure 4 ⑥.

(2) When drilled head bolts, screws, or other parts are grouped together, they are more conveniently safetied to each other rather than individually. The method by which two drilled head bolts are safetied is shown in figure 30 ③. It is to be noted that the wire is arranged between the bolt heads in such a manner that if either bolt begins to

loosen, the other will have force applied to it in a tightening direction. Thumbscrews of two hose clamps are safetied to each other as shown in figure 30 ④. In figure 30 ⑤ is shown the method by which two fillister head screws are safetied.

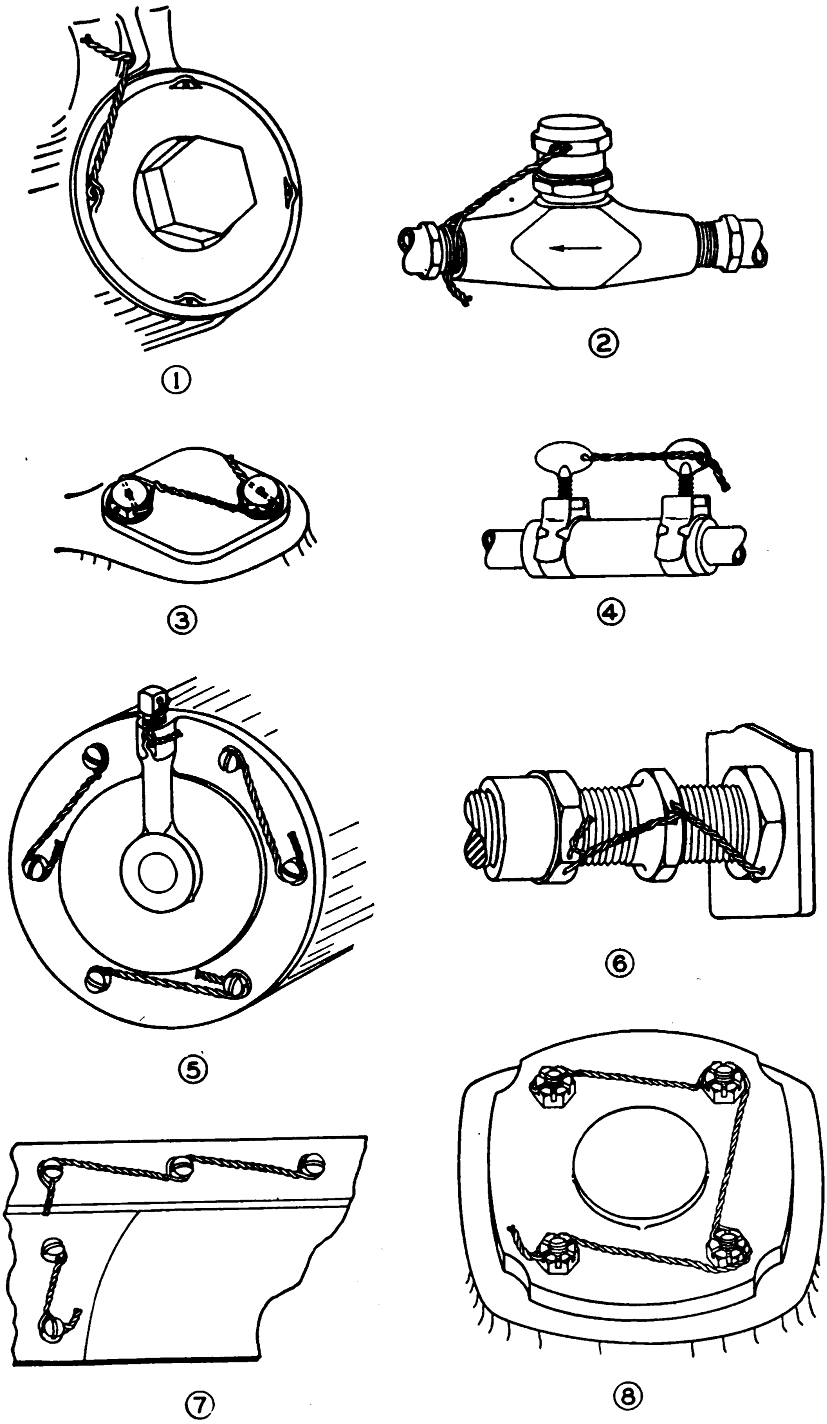


FIGURE 30.—Application of safety wire.

(3) The method by which three fittings or parts are safetied is shown in figure 30 ⑥ and ⑦. Where many parts are grouped, the general custom is to have three of such parts safetied together; occasionally, however, more than three are safetied together.

(4) If a castellated nut is used on a stud which is threaded into an assembly, a cotter pin will prevent the nut from working loose but will not prevent the stud from working out. Both the stud and the nut may be safetied by the use of wire as shown in figure 30 ⑧. If one nut and stud combination is to be safetied, the wire may be anchored to an adjacent part of the assembly.

h. A turnbuckle may be safetied as follows:

(1) The turnbuckle is first adjusted to the proper tension (not more than three threads should be exposed on either end). The wire is

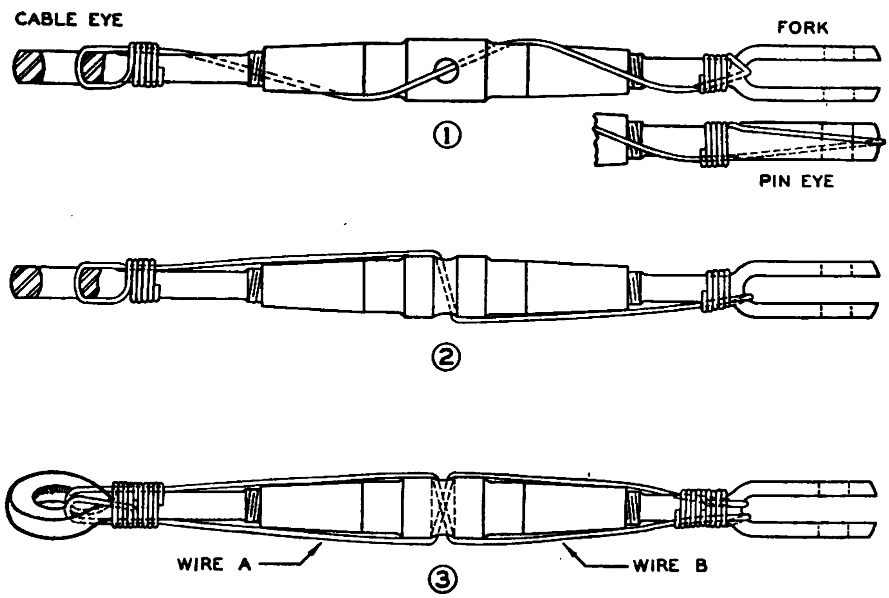


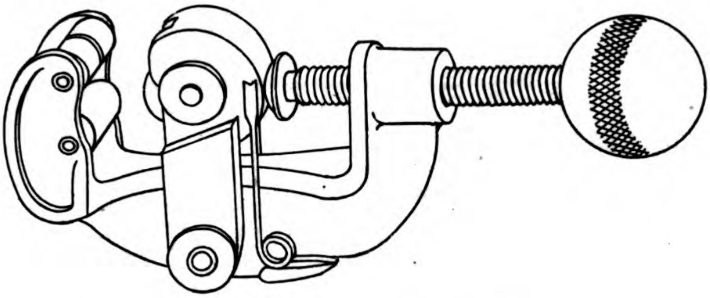
FIGURE 31.—Application of safety wire with turnbuckles.

threaded through the hole in the middle of the barrel so that half of the wire extends from either side of the hole (fig. 31 ①). The wire is then spiraled around the barrel in the direction the barrel turns to tighten, and then passes through the cable eye or fork. The end of the wire is wrapped around the shank for at least four turns. A check may be made to see if the wire tightens when the barrel is turned in the direction to loosen. With a turnbuckle having a pin eye end, the wire is brought around the outside of the pin eye and wrapped around the shank.

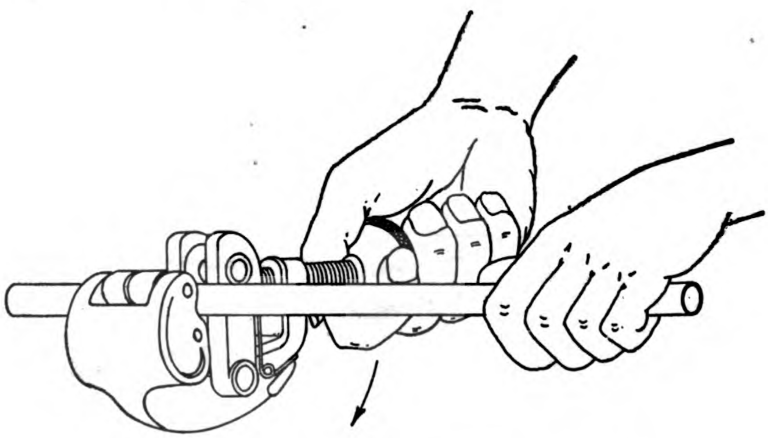
(2) The turnbuckle may also be safetied without spiraling the wire around the barrel as shown in figure 31 ② or with two untwisted wires as shown in figure 31 ③. In the latter method wires A and B are first

placed through the barrel hole. Wire A is then drawn through the eye or fork and continued straight back toward the barrel and held firmly on the shank. Wire B is drawn through the eye or fork and looped over the shank and wire A for at least four turns. Wire A is then looped around the shank for at least four turns.

43. Tube cutting, bending, and flaring.—The cutting, bending, and flaring of tubing are important operations in the maintenance of aircraft plumbing systems. Care should be exercised in performing



① TUBE CUTTER



② TUBE CUTTER IN USE

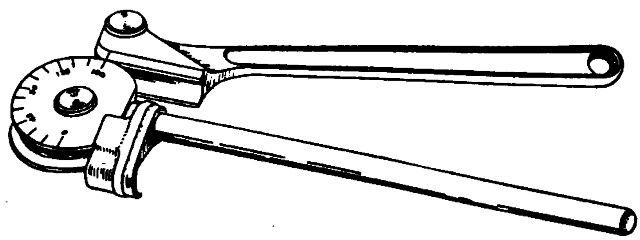
FIGURE 32.—Tube cutter and application.

these operations to guard against defective connections or failure in any part of the system.

a. Tube cutting.—(1) When tubing is to be cut, it is necessary to produce a square end, free from burs. This is especially necessary if a flared tube connection is to be made. A clean square cut may be made with a tube cutter (fig. 32 ①). This tool is adaptable for use with copper, brass, or aluminum tubing. The tube is placed in the cutting tool as shown in figure 32 ② with the cutting wheel at the point where the cut is to be made. The tool is rotated about the tube and a

light pressure is applied to the cutting wheel by turning the handle. Care should be exercised not to apply too much pressure to the cutting wheel, inasmuch as the tube may thus become deformed. The bur formed on the inside of the tube is carefully removed with a knife or scraper. The use of a reamer is not advisable because of the possibility of flaring the tube or chamfering the inside.

(2) If a tube cutter is not available or if tubing of hard material is to be cut, a fine-toothed hacksaw, preferably 32 teeth per inch, may be used. The end of the tube is filed square and smooth. The



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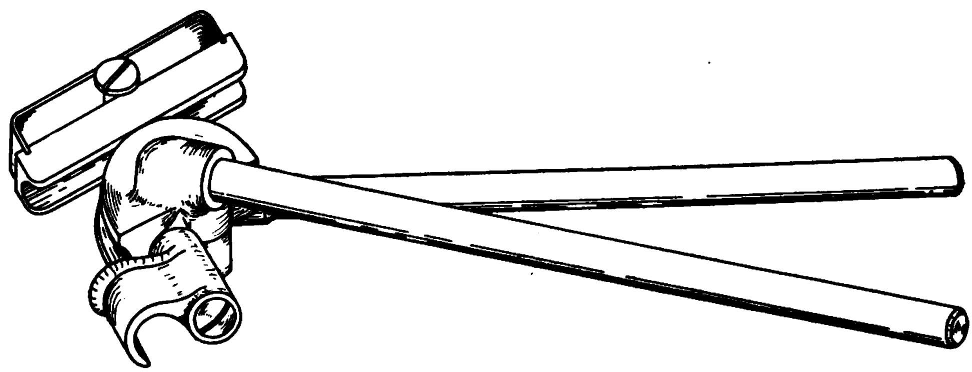


②

FIGURE 33.—Hand tube bender.

file may be lightly applied to the outside of the tube to remove the external bur. The bur on the inside of the tube may be removed with a scraper. A convenient method of holding small tubing when cutting with a hacksaw is to place the tube in a combination flaring tool (fig. 36) and then clamp the tool in a vise. The cut should be made a short distance from the tool to prevent damage to it by the hacksaw or file. All filings and cuttings should be carefully removed from the tube to prevent damage to the various devices in the system.

b. Tube bending.—(1) The important consideration in bending tubing is to produce a smooth, even bend without flattening or buckling of the tube. The hand tube bender (fig. 33) is a convenient device for making smooth and accurate bends in thin-walled tubing of soft material. The type shown in figure 33 ① is available in four sizes to accommodate tubing ranging from $\frac{3}{16}$ to $\frac{3}{8}$ inch (by sixteenths)

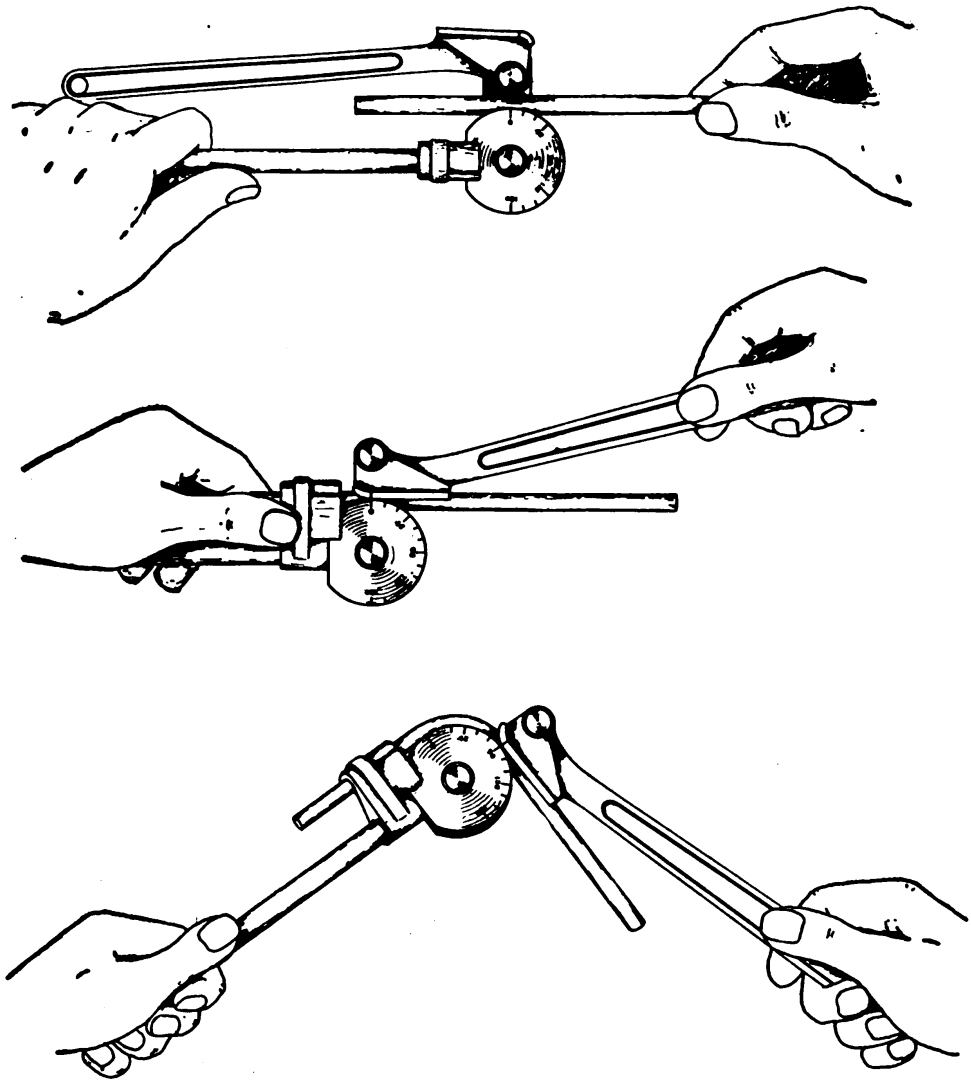


FIGURE 34.—Methods of using hand tube bender.

outside diameter. The angle of bend in the tubing is indicated by the graduations on the block of the tube bender in divisions of 15°, ranging from 0° to 180°. The type shown in figure 33 ② is available in four sizes to accommodate tubing $\frac{7}{16}$, $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ inch outside diameter. Figure 34 illustrates the method of using a hand tube bender.

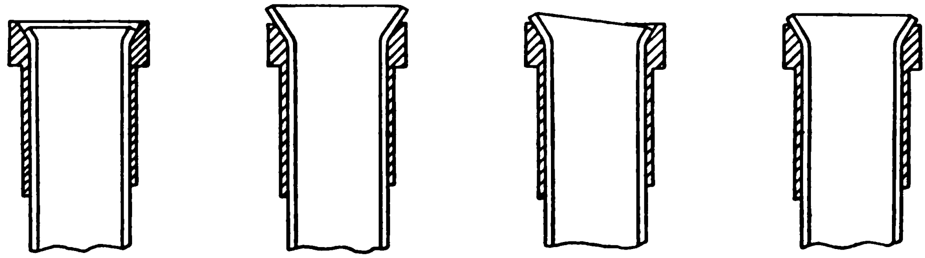
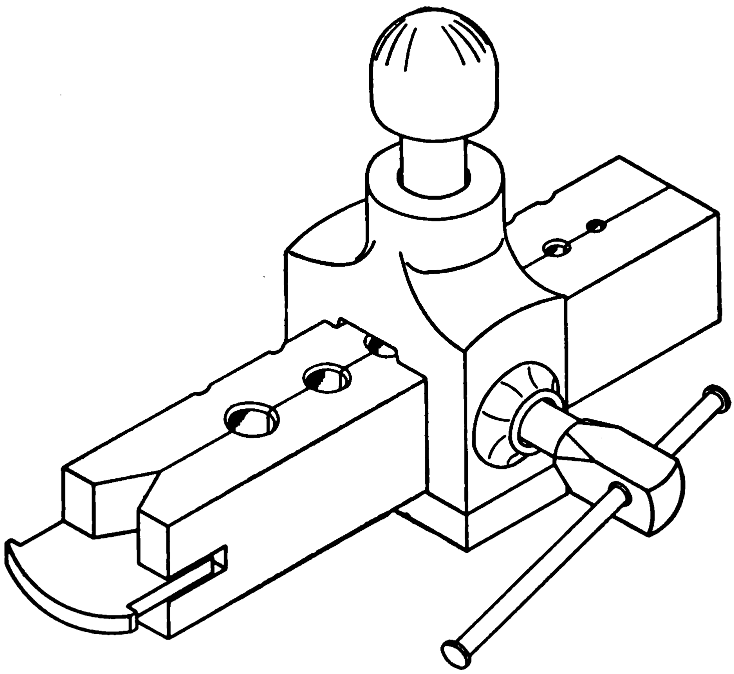
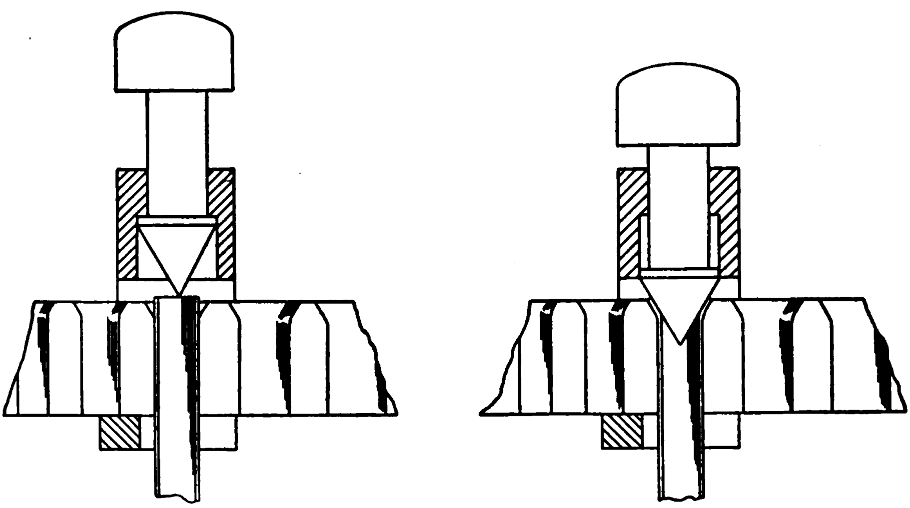


FIGURE 35.—Incorrect and correct forms of tubing flare.



① COMBINATION FLARING TOOL



② COMBINATION FLARING TOOL IN USE

FIGURE 36.—Flaring tools.

(2) In depots and maintenance shops, tube bending machines are generally employed to bend tubing of various materials; with such equipment, proper bends may be accomplished in large diameter and hard material tubing. In some instances, a special fusible filler is used as an aid in bending the tube.

c. Flaring.—(1) The flared tube solderless fitting (fig. 12 ⑨) is frequently subjected to extremely high pressures. Therefore the flare on the tubing must fit the fitting. If the flare is not properly made on the tube, the connection may fail. Figure 35 shows common flare errors and the correct form of flared tube end. An insufficient flare may leak or pull out. An excessive flare will interfere

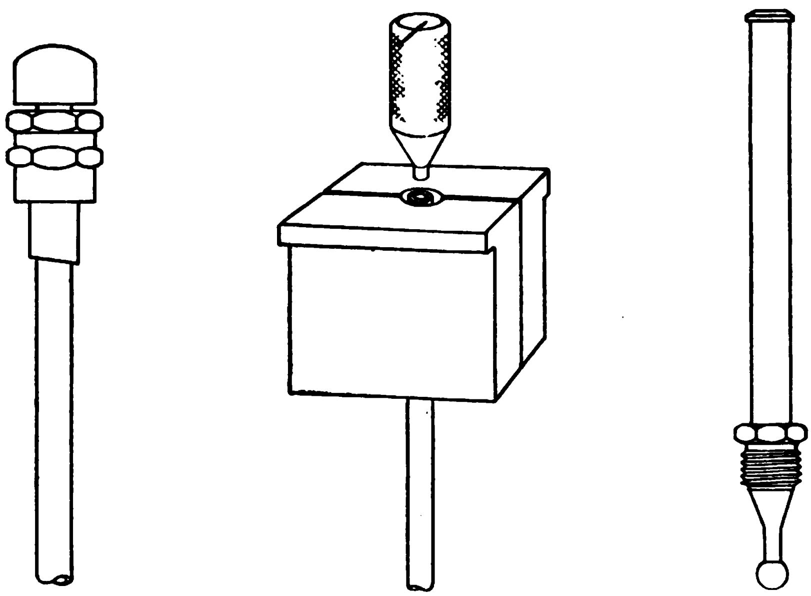


FIGURE 36.—Flaring tools—Continued.

with proper engagement of the screw threads on the fitting. A crooked flare will result if the tubing is not cut squarely. The flare and tubing must be free from cracks, dents, nicks, scratches, or other defects. If the flare is not properly made, a proper seat cannot be made by means of excessive tightening of the fitting. In the assembly of tubes ⅜ inch and smaller, special care should be exercised so as not to apply excessive wrench torque. Dimensions of tube flares and allowable wrench torque for assembling fittings are given in table IX.

(2) The combination flaring tool (fig. 36 ① is designed to accommodate tubing ranging from ⅛ to ½ inch outside diameter. The sleeve and nut are slipped over and down on the tubing before the flare is made. The tubing only is placed in the proper gage hole, clamped in position, and the flaring pin centered over the end of the

tubing. The flare is then made by striking the flaring pin several light blows with a medium weight hammer or rawhide mallet. The action of the flaring pin is shown in figure 36 ②. During the operation, the tool is supported by one hand by grasping the tubing underneath the tool. This tool is not used with hard-drawn or steel tubing.

(3) Other types of flaring tools are also available for use with a single size of tubing.

(*a*) The hammer type flaring tool (fig. 3 ③) is held in the hand during the flaring operation and is adaptable for soft tubing of moderately heavy wall thickness.

(*b*) The flaring block (fig. 36 ④) is adaptable for use with heavy-walled tubing, alloy steel, and other hard material tubing.

(*c*) The ball type flaring tool (fig. 36 ⑤) is inserted into the tube up to the tapered portion and the flare accomplished by rotating the tool in the tube with a moderate downward and outward pressure. After the flare has been formed, the threads on the tool may be engaged with the coupling nut and tightened to properly seat the flare on the sleeve. This tool is adaptable for use with soft, thin-walled tubing.

TABLE IX.—*Dimensions of tube flares and allowable wrench torque*

Tube outside diameter (inch)	Flare outside diameter		Wrench torque (inch-pounds)			
			(Aluminum alloy tubes)		(Steel tubes)	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
3/16	0.297	0.312	--------	--------	30	70
1/4	.344	.359	40	65	50	90
5/16	.406	.421	60	100	70	120
3/8	.469	.484	75	125	90	150
1/2	.641	.656	150	250	150	250
5/8	.766	.781	200	350	--------	--------
3/4	.922	.937	300	500	--------	--------
1	1.172	1.187	500	750	--------	--------

44. Soldering.—The process of securely joining metallic surfaces by use of a bond of metallic alloy (solder) which fuses at a lower temperature than the surfaces to be joined is designated "soldering." This differs from welding wherein the metals are joined by being fused together. The process of soldering is referred to as "soft soldering" when the solder used to make the bonding joint is an alloy which melts readily, "hard soldering" when the solder requires at least a red heat to fuse, and "brazing" when the solder is essentially an alloy of copper and zinc (brass) or copper, zinc, and tin. Hard soldering is employed where high tensile strength, high melting point, and resistance to vibration and shock are required. Brazing

may be done on such metals as copper, brass (with high melting point), bronze, and plain carbon steels.

a. Soft solder is generally used on such work as sheet metal seaming, wire splicing, low-resistance electric connections, etc. Solder designated as "grade A" (half and half) contains a lead-tin constituency of 99.65 percent (with a tin minimum of 49 percent) and small percentages of copper and antimony. Grade A solder melts at approximately 360° F. and is completely liquid at approximately 415° F. Inasmuch as lead and tin are relatively soft metals, soldered material should not be subjected to stresses which may tend to weaken the bond. The steady application of very small loads will cause solder to yield. Solder should not be used on parts where a failure of the soldered joint would endanger the safety of the aircraft; therefore, solder should not be used in the attachment of fittings or ribs to main structural members, fuselage joints, or control mechanisms, unless the solder is used simply to prevent relative movement of the parts and the load on the joint is carried by wrapping, rivets, pins, bolts, etc. Solder should never be used for filling cracks or pits to produce a smooth appearing finish.

(1) Surfaces of metal to be joined must be physically and chemically clean, or solder will not adhere, resulting in serious impairment of strength of bond. Initial surface cleaning is accomplished with sandpaper, emery cloth, scraper, or file, and by wiping away any free particles. When the metal is heated preparatory to applying solder, a coating of oxide invariably forms on its surface. The presence of this oxide tends to prevent a close union between the fusing solder and the metal; to free the surface of this coating and to prevent oxidation during application of solder, a substance is used which has a lower melting point than the solder and is known as "flux." A flux acts to "cut" the coating of oxide, exposing the surface of the metal and thus permitting a firm bond between the solder and the metal. Fluxes generally used are:

(*a*) Zinc chloride, ammonium chloride, and hydrochloric acid; these fluxes are corrosive by nature and should never be used on electric connections or wires in the absence of authorization and explicit directions, inasmuch as the corrosive action of any remaining flux will continue and eventually seriously weaken or eat through the metal. Also, for use on other work it is advisable to remove any remaining flux with a neutralizing agent and water. Zinc chloride is commonly used, and is employed on iron, steel, zinc, and other metals.

(*b*) Rosin, for use on copper, tin, brass, and lead; this flux is noncorrosive and may be used on electric connections and wires. Rosin

is available as a paste, powder, liquid, and as an integral flux core of solder in wire form.

(2) The blowtorch (fig. 37 ①), commonly used as a source of heat for the soldering copper, is prepared for operation by first filling the tank (with jet valve closed) to about three-fourths of its volume with clean, unleaded gasoline. Sufficient air is pumped into the tank to cause the gasoline to flow when the jet valve is opened slightly; if it is difficult to produce pressure the leather on the plunger of the blowtorch pump should be greased or oiled. The palm of the hand is placed over the end of the burner to direct the flow of gasoline into the preheating cup. When the cup has been filled, the jet valve is closed and the gasoline in the cup ignited with a match while standing at

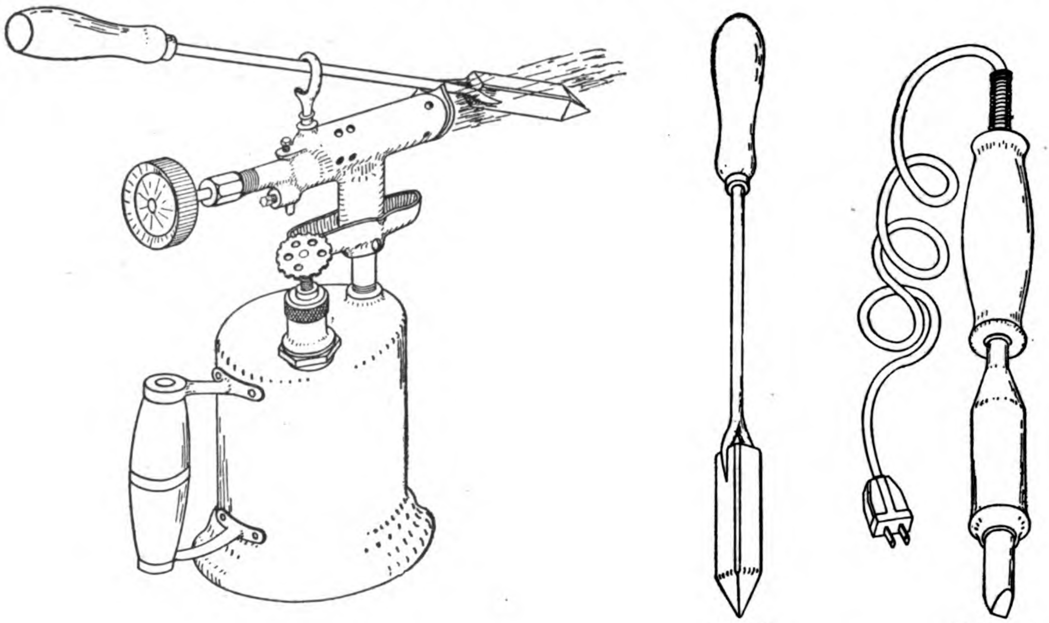


FIGURE 37.—Soldering equipment.

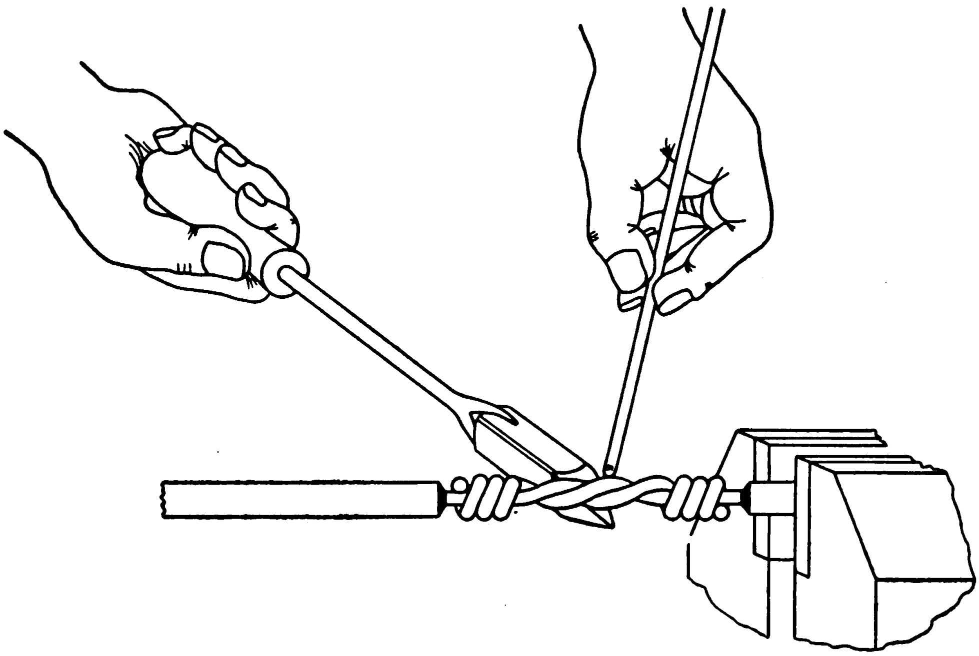
arm's length from the blowtorch. The resulting yellow flame will heat the burner. Shortly before the cup flame dies, the jet valve is opened to allow gasoline from the tank to flow through the burner and ignite from the heat of the latter, the resulting flame gradually turning from yellow to blue, and blowing strongly with a few additional strokes of the pump plunger. In the event the burner flame continues yellow and slow, the end of the burner may be held close to a steel plate in order to concentrate the flame around the burner, causing it to heat sufficiently to produce a blue flame. The torch may be extinguished by closing the jet valve. After the flame is extinguished, the jet valve should be opened a full turn to allow the gasoline vapor under pressure to wash the carbon from the jet. If the jet is per-

mitted to remain slightly open, wear and sticking will be avoided. The tank should be emptied of gasoline when not in use.

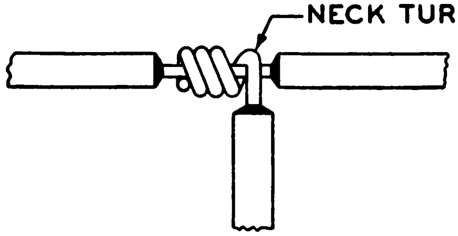
(3) In order that the soldering copper (fig. 37 ②) may be used effectively, the soldering end of the bit must be "tinned," that is, coated with solder; this is done to a new copper or one from which the coating of solder has been burned. The soldering end of the copper bit is thoroughly cleaned of oxide coating by filing smooth and then heated until prismatic colors begin to appear on its surface. Tinning is accomplished by rubbing each face of the soldering end of the bit in the clean, shallow depression of a wood block into which some solder and rosin have been melted, the rosin enabling the solder to adhere to the copper; surplus solder is removed with a damp cloth. A brick of ammonium chloride (sal ammoniac), itself a flux, may be used instead of a wood block and rosin, but inasmuch as this flux is strongly poisonous and corrosive, the fumes which result from touching the hot copper to the brick should not be inhaled. When heating a soldering copper preparatory for use, care should be exercised to avoid heating to a temperature at which the tin coating will burn off, a condition which results soon after the bit begins to turn dark in the flame. When necessary, the bit of the soldering copper should be repointed by heating to a bright red and forging on an anvil, distributing the hammer blows on each face successively, with even force. Annealing the bit by reheating to bright red and plunging it into water will improve its radiating characteristics. The bit of the electric soldering copper should be removed from its socket when forging or when holding it in a vise for filing, to avoid damage to the electric heating element.

(4) The strength of a soldered joint is dependent not only upon clean surfaces but also upon other factors which are of equal importance. Surfaces to be joined must be properly fitted and have adequate overlapping or contact area; the solder must not be relied upon to correct any omission of care in this respect. The effectiveness of the joint will depend upon the amount of heat the soldering copper transfers to the contact area of the metal, temperature of which should be above the melting point of the solder to insure ready flow of the latter. Thick metal may be carefully preheated with a blowtorch, care being exercised to avoid oxidation which will result if the flame comes into direct contact with that portion of the surface to be joined. The soldering copper selected should be as large as is adaptable for the work, inasmuch as a large copper (as compared with a small one) will retain more heat and so transmit more, thus making frequent reheating unnecessary. If the area to be joined is comparatively large, two plain coppers may be advantageously employed, the one being heated while

the other is in use. A copper which is too hot will transfer excessive heat and cause the solder to sputter, and if not hot enough will cause the solder to pile up; therefore, the temperature of the copper should be such as to transmit sufficient heat through the metal to be joined to cause the solder to flow readily. After a soldered union is completed, it should not be disturbed until the solder has completely cooled and



① WESTERN UNION SPLICE



② TAP SPLICE

FIGURE 38.—Soldering wire splices.

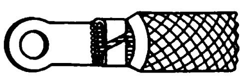
hardened; water should not be used for cooling the union, inasmuch as this action will produce contraction of the metal and weakening stresses.

(5) Soldering is commonly employed with the following:

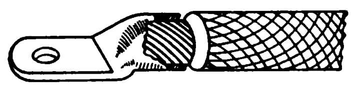
(*a*) *Wire splice*.—When soldering with splices, the copper bit is held against the underside of the long twists of the Western Union splice (fig. 38 ①) or turns (the neck turn is not soldered) of the tap

splice (fig. 38 ②) and the rosin-cored solder drawn in from above by the heat of the wire. If rosin-cored solder is not used, the wire is first treated with flux. In this and in other wire connections close attachment between the parts to be joined must be assured before the application of solder; this produces a strong bond which does not place dependence upon the solder to carry the current.

(*b*) *Clamp terminal connection* (*light copper soldering lug*).—This connection (fig. 39 ①) is prepared by first tinning the stranded wire end and terminal wire clamp; the copper bit is applied to the underside of the terminal, the heat fusing the tinning on the terminal and the wire and spreading it evenly over the joint. Where the parts to be joined are first tinned (as in this type of connection) and the tinning fused, the soldering process is known as "sweating." Tinning may be accomplished by dipping, or by fusing the solder on the wire with heat transferred to the wire by contact with the soldering copper.



① CLAMP TERMINAL CONNECTION



② CUP TERMINAL CONNECTION

FIGURE 39.—Soldered terminal connections.

(*c*) *Cup terminal connection* (*heavy copper soldering lug*).—An effective procedure for soldering this type of connection (fig. 39 ②) is as follows:

1. Remove the insulation from the end of the wire for a distance slightly in excess of the depth of the cup.

2. Clean the exposed wire, twist firmly to bring all loose strands into close contact, apply flux (rosin), and then tin the wire.

3. The terminal used should have a cup diameter (inside) only slightly larger than the diameter of the exposed wire. Clamp the terminal vertically in a vise, with the cup end up. Small pieces of wood may be used against the inside of the vise jaws to minimize loss of heat. Place a small quantity of flux in the cup and apply the heated soldering copper to the side of the cup, maintaining contact until the flux has boiled away.

4. Fill the cup approximately two-thirds full with molten solder. Apply the heated soldering copper to the side of the cup to keep the solder thoroughly molten.

5. Place the tinned wire end at the junction between the cup and soldering copper to raise the temperature of the wire approximately to that of the solder in the cup.

6. Insert the wire end slowly into the cup and then remove the soldering copper. Hold the wire in place until the solder has cooled.

(*d*) *Terminal connection to stainless steel cable.*—This bond is prepared by dipping the end of the cable to be soldered into a flux consisting of ½ pound of zinc chloride (soldering salts), one quart of water, and ⅓ fluid ounce (10 cc) of hydrochloric acid. Solder is applied with the copper or by dipping until the cable end is well tinned; the surplus tinning is removed and the cable end washed in a neutralizing solution consisting of 5 percent soda ash (sodium carbonate) and 1 percent potassium dichromate. All trace of the neutralizing solution is removed by washing in clean water. Soldering paste, specification 2–89, or a liquid flux made by dissolving ¼ pound of zinc chloride in 1 quart of water is applied to the fitting and tinned cable end. The joint is then heated, soldered, and allowed to cool. Following this it is necessary that the parts again be dipped in the neutralizing solution and washed in clean water.

(*e*) *Ignition manifold assembly.*—When it is necessary to repair a shielded ignition manifold assembly, only solder, specification 57–99–1 (lead and silver rod, ⅛-inch diameter), should be used because of its resistance to higher temperatures; this solder is applied with soldering copper, extreme care being exercised to prevent burning of any adjacent ignition cable insulation. Whenever possible, the ignition cable should be withdrawn from the parts to be soldered.

(*f*) *Bonding connection to shielding.*—When soldering bonded pigtails to flexible metal braid shielding, particular care must be taken to prevent damage to insulation. The proper procedure is to attach the pigtail temporarily to the shielding with one turn of soft copper wire. A noncorrosive flux such as rosin is used and a small quantity of solder is flowed into the braid by instantaneous contact with a hot iron. The insulation will be damaged with continued contact of a warm iron but not with quick contact of a hot iron.

(*g*) *Seaming.*—A lap seam (fig. 40) of thick metal or wide overlap may advantageously first be tinned. To insure that the joint is not disturbed during the soldering process, a tacking of solder may be used, or the joint held fast with pressure from a piece of wood or point of a file tang. It may be necessary to use some solder in addition to that supplied by the tinning and if the tacking does not furnish a sufficient quantity, a small amount may be added to the joint by contact with the heated metal and drawn into the seam as the soldering copper is slowly moved with even pressure over the width of the joint. If the metal parts to be joined are not first tinned, the entire amount of solder necessary for the joint is drawn

in by the action of the heat supplied to the joint by the soldering copper. The folded seam (fig. 41) is hammered with a mallet to insure a close fit, and then soldered by moving the soldering copper over the entire width of seam, drawing the solder into the joint. The joint may first be tinned (before the bend is made).

b. If solder is to be used on such parts as fuel, oil, and high pressure lines, manifold housings, attaching clips, etc., a grade of solder is employed which possesses a high tensile strength and resistance to changes of temperature, vibration, and shock. A hard solder containing silver in varying percentages in combination with copper and zinc is adaptable for such use, and is designated as silver solder. The surfaces to be soldered must be thoroughly cleaned and a flux (powdered borax is suitable) added. The surfaces to be joined are fitted securely and heat applied, usually with a mild, moving oxyacety-

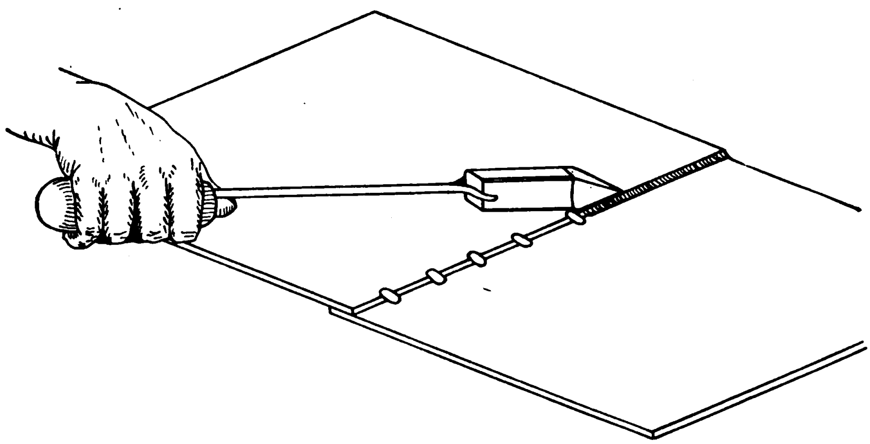


FIGURE 40.—Soldering lap seam.

lene flame (acetylene and air flame may be used on light gage metal) held approximately ½ inch from the work. When the flux begins to flow freely, the solder is placed in a position where it could, if molten, freely run into the joint. The heat is continued until the solder fuses and flows into the joint. All traces of flux should be removed after the joint has set by use of a suitable neutralizing solution for the particular metal, followed by a water rinse. If the melting point of any metal to be soldered nearly approaches that of the solder, the latter should be placed into position before the application of heat and the heat withdrawn as soon as the solder has thoroughly fused and filled the joint. When soldering metals of different thicknesses or unequal heat conductivity, care should be exercised to raise the temperature of the metals to the melting point of the solder at the same time.

c. Brazing is similar to hard soldering; the solder used is generally one consisting of copper and zinc and small percentages of other

metals. Brazing solders are available with different percentages of component metals with corresponding different melting points varying from approximately 1,600° F. to 1,825° F. The solder is selected in accordance with best adaptability to, and the melting point of, the metals to be joined. Surfaces to be joined must be thoroughly clean and free of oxide. A flux may be used consisting of borax and boric acid. The actual brazing may be accomplished with a torch, furnace, or bath of molten solder.

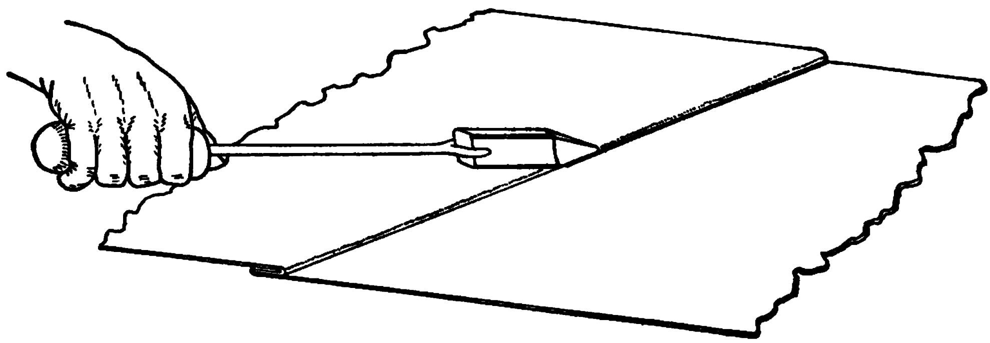


FIGURE 41.—Soldering folded seam.

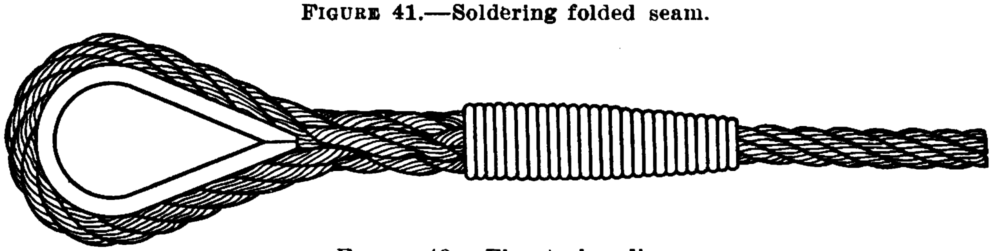


FIGURE 42.—Five tuck splice.

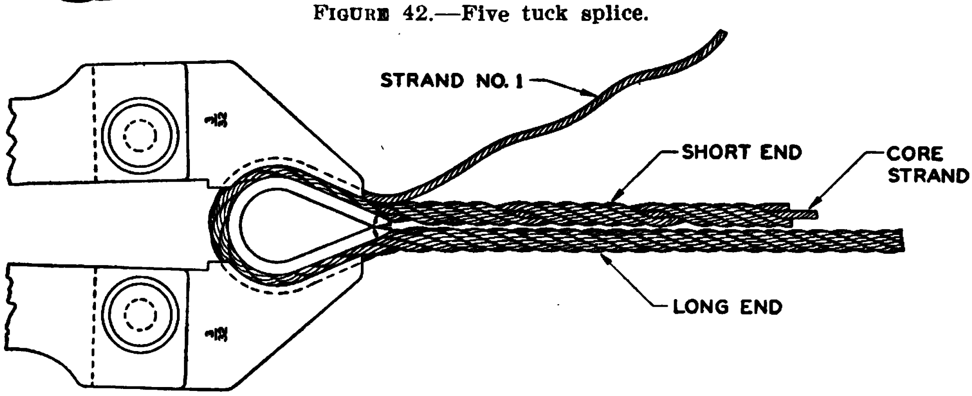


FIGURE 43.—Holding cable for splicing.

45. Cable terminal splicing.—A cable terminal is made by looping the end of the cable around a cable thimble or bushing and securing the end by splicing (tucking) or wrapping.

a. Spliced cable terminal.—(1) The five tuck splice (fig. 42) is applied to 7 by 7 flexible cable and 7 by 19 extra flexible cable 1/8 inch and larger. The following tools and materials are used in making this splice:

(*a*) A marlin spike for separating the strands and wires of the cable.

(*b*) A suitable clamp such as a bench cable splicing vise or a hand cable splicing vise to hold the cable. If a vise is not available, a waxed cord tightly wrapped around the thimble and cable may be used as a substitute.

(*c*) A small wood, fiber, or copper mallet for use in pounding the splice.

(*d*) A hard wood block to serve as an anvil on which to pound the splice.

(*e*) Six-cord thread having a breaking strength of 32 pounds, for serving the finished splice.

(2) The step by step procedure for making the splice follows:

(*a*) Loop cable around thimble or bushing, leaving about 8 inches free to make the splice. This end will be referred to as the "short" or free end (fig. 43). The thimble points should be bent back approximately 45°.

(*b*) Clamp loop in correct size jaws of cable splicing vise. Clamp the cable splicing vise in a bench vise with the jaws of the cable splicing vise in a horizontal position pointing away from the mechanic; right and left side of loop is determined with the short end at the mechanic's left.

(*c*) Number 1 strand of the "short" end is selected nearest the thimble point and is unlaid, as are all other strands at the time each is tucked. Tuck under three strands (A, B, C) of the long end. This tuck is straight through the cable above the core and may be considered as being made from left to right (fig. 44 ①).

(*d*) Since the strands are numbered consecutively in clockwise direction, number 2 strand is to the left of strand number 1. Tuck number 2 in with number 1, under two strands (A and B) from left to right (fig. 44 ②).

(*e*) Tuck number 3 in with numbers 1 and 2, under one strand (A) from left to right (fig. 44 ③).

(*f*) Tuck core strand (black dot), the same as number 2, but bring it out below number 2 (fig. 44 ④). Tie core strand to long end for identification.

(*g*) Tuck number 6 in with the above strands (numbers 1, 2, 3, and core), passing over two strands (E and F) from left to right (fig. 44 ⑤).

(*h*) Tuck number 5 in where number 6 comes out, going around strand E and coming out between strands E and F (fig. 44 ⑥).

(*i*) Tuck number 4 in where number 5 comes out, going around one strand (F) and coming out where numbers 1, 2, 3, 6, and core go in (fig. 44 ⑦).

(*j*) Pull all strands tight and beat down snug, completing the first round of tucks. There will now be one strand emerging from each space between the strands of the long end except where the core comes out with the number 2 strand.

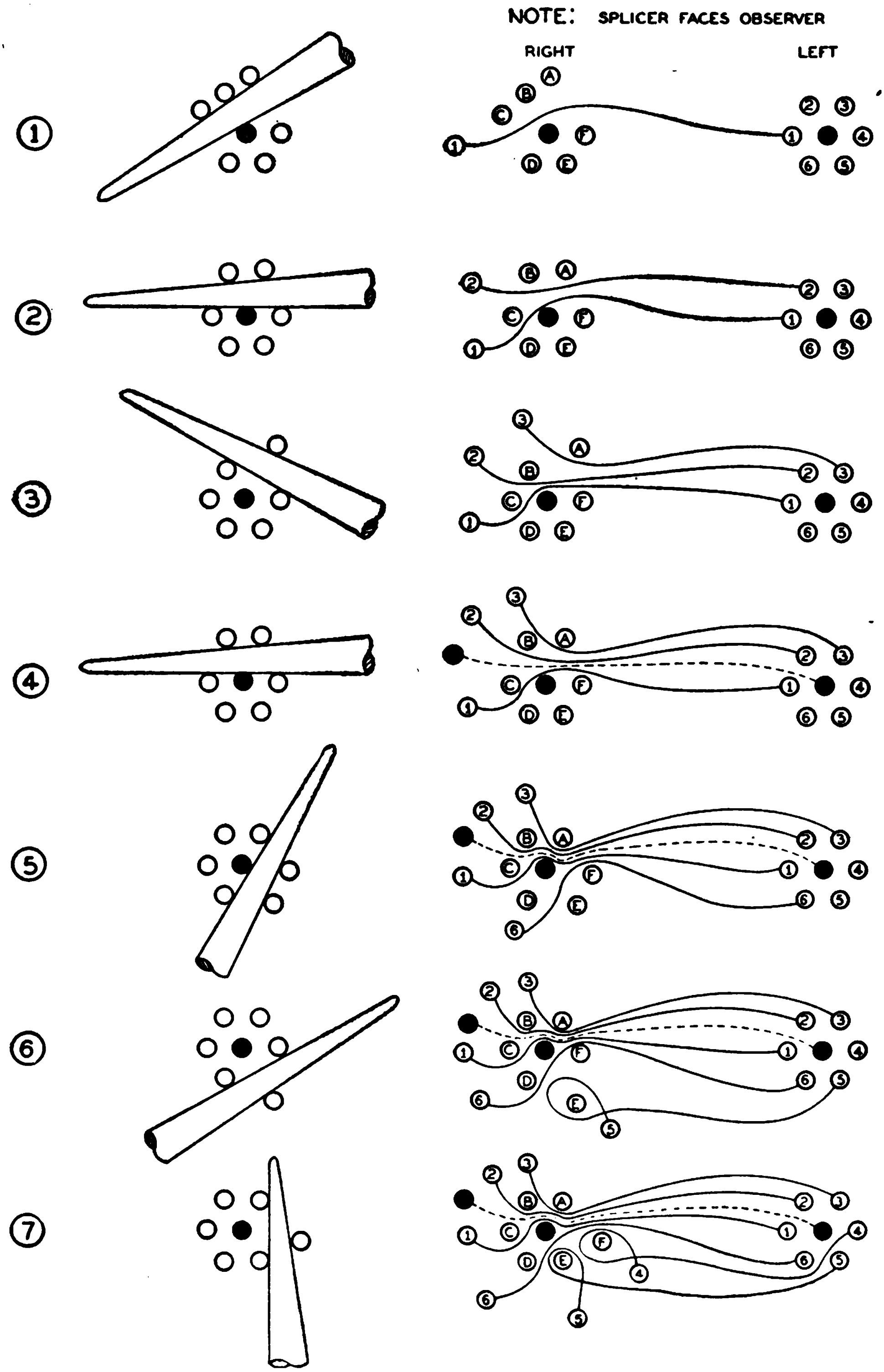


FIGURE 44.—Procedure for first tucks in cable splice.

(*k*) Begin second round of tuck by tucking the first strand to the right of the free core strand, going over and under one strand toward the left.

(*l*) Take each strand consecutively to the left and tuck over one strand and under one. The last strand tucked should come out in the same space as the core and above it.

(*m*) Pull all strands tight and beat down, completing the second round.

(*n*) Proceed with a third round of tucks in the same manner as described for the second round and finish by beating the strands down.

(*o*) Separate each strand in half, and tuck one-half of each strand in the same manner as described for the second and third rounds.

(*p*) Cut off the six remaining untucked half strands as well as the core strand and beat down snug, completing the fourth tuck.

(*q*) Halve all strands again and proceed the same as in step (*o*). When the round is complete, beat down and cut off all strands.

(*r*) Flatten the thimble points against the splice and finish by serving with cord, wrapping from 1/4 inch beyond the fifth tuck to a point midway between the second and third tucks. Make five or six loose wraps over the thumb or finger and insert the loose end of the cord under these wraps from the thimble toward the taper. Draw the wraps up tightly and pull the end up snugly. Cut the end of the cord off even with the surface.

(*s*) Complete the splice by applying two coats of orange shellac.

b. *Wrapped cable terminal.*—(1) This type of cable terminal is for use on nonflexible 19-strand cable, and may also be applied to flexible cables 3/32 inch and less in diameter. It is seldom used on aircraft, but is used for articles such as tow target releases. The materials used for making this terminal are:

(*a*) Grade A soft solder.

(*b*) Soft annealed steel wire, thoroughly tinned, for wrapping splice.

(*c*) Stearic acid or a mixture of stearic acid and rosin for the flux.

(2) The general procedure for the splicing operation is as follows:

(*a*) Solder and taper the end of the cable.

(*b*) Thoroughly clean the length of the cable to be wrapped and apply a coat of flux; then loop cable over a suitable thimble and hold in place with a clamp.

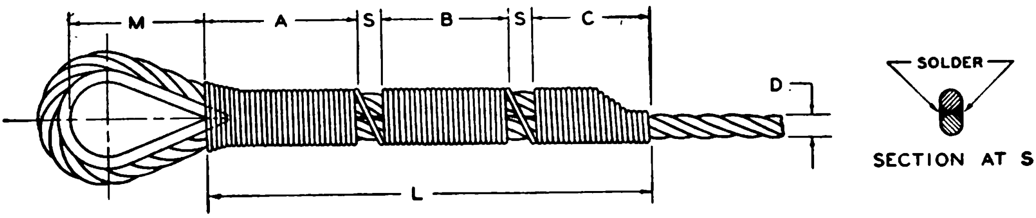
(*c*) Apply the wrapping wire, under constant tension, and space according to the dimensions given in table X.

(*d*) Solder the terminal by dipping in hot solder until all spaces and inspection gaps are filled even with the wrapping wire.

(*e*) Wipe splice with a rag to produce a smooth finish. Never use files or abrasive wheels for smoothing the solder.

(3) Soldered terminals for stainless steel cable are made in the same manner with the exception of the flux used. A suitable flux for this purpose consists of a mixture of ½ pound of zinc chloride, 1 quart of water, and ⅓ fluid ounce (10 cc) of hydrochloric acid. When the terminal is completed the flux must be neutralized in a solution consisting of 5 percent sodium carbonate (soda ash) and 1 percent potassium dichromate, followed by a thorough washing in clean water.

TABLE X.—*Wrapped and soldered cable terminals*



D	L	A	B	C	S	M	Thimble part No.	Wrapping wire	
								Diameter wire	Length
All dimensions in inches									
1/16	1⅞	⅝	½	½	⅛	¾	AN100-3	0.020	25
3/32	2¼	¾	⅝	⅝	⅛	¾	AN100 3	.020	37
⅛	2¾	1	¾	¾	⅛	¾	AN100-4	.025	58
5/32	3⅜	1⅛	1	1	⅛	⅞	AN100-5	.025	82
3/16	3⅝	1¼	1	1	3/16	1⅛	AN100-6	.035	109
¼	4½	1½	1¼	1¼	¼	1½	AN100-8	.035	159

[A. G. 062.11 (5-5-42).]

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